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RELIABILITY OF NONDESTRUCTIVE INSPECTIONS

FINAL REPORT

December 1978

Prepared by The Lockheed-Georgia Company

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THE RESULTS OF A FOUR-YEAR AIR FORCE LOGISTICS COMMAND PROGRAM TO DETERMINE THE RELIABILITY OF AIR FORCE NONDESTRUCTIVE INSPECTION CAPABILITY ARE PRESENTED. THE REPORT COMPLETELY DESCRIBES THE PROGRAM - ITS OBJECTIVES, SCOPE, PLANNING AND LOGISTICS, PARTICIPANTS, DATA COLLECTION, ANALYSIS, CONCLUSIONS AND RECOMMENDATIONS. ACTUAL AIRCRAFT STRUCTURAL SAMPLES CONTAINING FATIGUE DAMAGE WERE TRANSPORTED TO 21

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DIFFERENT AIR FORCE BASES AND DEPOTS, WHERE APPROXIMATELY 300 AIR FORCE TECHNICIANS PERFORMED ULTRASONIC, EDDY CURRENT, PENETRANT AND RADIOGRAPHIC NONDESTRUCTIVE INSPECTIONS (NDI) ON THE SAMPLES. THE SAME DETAILED NDI PROCEDURES WERE FOLLOWED BY ALL PARTICIPATING TECHNICIANS. THE INDIVIDUAL RESULTS WERE RECORDED AND ACCUMULATED IN TERMS OF "FINDS", "MISSES" AND "FALSE CALLS" COMPARED TO A PRELIMINARY KNOWLEDGE OF ACTUAL FLAW LOCATIONS. A DETAILED TEARDOWN INSPECTION OF THE SAMPLES AT THE END OF THE PROGRAM VERIFIED AND REFINED ACTUAL FLAW TABULATIONS. RESULTS WERE COMPUTERIZED FOR DATA STORAGE AND RETRIEVAL AND ANALYZED FOR EACH (NDI) METHOD AND STRUCTURE SAMPLE TYPE TO PROVIDE DETECTION PROBABILITY VERSUS FLAW SIZE (POD) CURVES. OTHER ANALYSES PROVIDED POD CURVES FOR YEARS TRAINING OR EXPERIENCE, AGE, ETC. THE PROGRAM RESULTS INDICATE THAT AIR FORCE NDI NEEDS IMPROVEMENT IN SEVERAL SPECIFIC AREAS IN ORDER TO MEET EXISTING REQUIREMENTS FOR INSPECTION OF AIR FORCE HARDWARE. SOME CONCLUSIONS WERE DERIVED CONCERNING FACTORS THAT APPARENTLY AFFECT AIR FORCE INSPECTION RELIABILITY. RECOMMENDATIONS FOR MAKING BOTH SHORT TERM AND LONG TERM IMPROVEMENTS IN NDI PROFICIENCY ARE PRESENTED.

FOREWORD

This Final Report was prepared in accordance with DI-S-3601A and is submitted in compliance with the following contractual requirements: CDRL Sequence Number A002, Contract F41608-76-D-A005, Order 0017; CDRL Sequence Number 002, Contract F41608-77-D-A021, Order 0043; and CDRL Sequence Number 002, Contract F41608-77-D-A021, Order 0045. The report covers all work done under the basic contract and the additional supplementary contracts during the period July 1974 through December 1978.

The Program was administered by the U. S. Air Force San Antonio Air Logistics Center, Kelly Air Force Base, Texas, under the direction of Mr. B. W. Boisvert, Chief, Air Force Program Section, MMETP. The Lockheed-Georgia Company, Marietta, Georgia, was the prime contractor for the Program with Mr. William H. Lewis as the Lockheed Program Manager. Mr. William H. Sproat was the Principal Engineer throughout the Program and was assisted by Mr. James M. Hamilton and Mr. Joseph L. Arnold in the computerization of data, Mr. Carl E. Bronn in statistical analyses, and Mr. William M. Pless in procedure preparation and editorial review. Mr. Bruce D. Dodd was responsible for the data acquisition portion of the Program, transporting the test samples and associated hardware to each of the Air Force installations and coordinating the technician inspections. Lockheed has assigned this report the number LG79ER0011 for internal control purposes.

The Contractor wishes to express appreciation for the hospitality and support received at each Air Force field and depot installation that participated in the program and for the complete cooperation, without which the success of the program would not have been possible. The support and guidance from the Air Force Materials Laboratory, in particular Mr. Ken Shimmin and Mr. Fred Mullins, is acknowledged and sincerely appreciated.

ABSTRACT

The results of a four-year Air Force Logistics Command program to determine the reliability of Air Force nondestructive inspection capability are presented. The report completely describes the program - its objectives, scope, planning and logistics, participants, data collection, analysis, conclusions and recommendations. Actual aircraft structural samples containing fatigue damage were transported to 21 different Air Force bases and depots, where approximately 300 Air Force technicians performed ultrasonic, eddy current, penetrant and radiographic nondestructive inspections (NDI) on the samples. The same detailed NDI procedures were followed by all participating technicians. The individual results were recorded and accumulated in terms of "finds", "misses" and "false calls" compared to a preliminary knowledge of actual flaw locations. A detailed teardown inspection of the samples at the end of the program verified and refined actual flaw tabulations. Results were computerized for data storage and retrieval and analyzed for each NDI method and structure sample type to provide detection probability versus flaw size (POD) curves. Other analyses provide POD curves for years training, experience, age, etc. The program results indicate that Air Force NDI needs improvement in several specific areas in order to meet existing requirements for inspection of Air Force hardware. Some conclusions were derived concerning factors that apparently affect Air Force inspection reliability. Recommendations for making both short-term and long-term improvements in NDI proficiency are presented.

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SUMMARY OF CONCLUSIONS

The conclusions presented in this report are based on the data obtained during the conduct of this program which used current NDI technology and equipment available at participating Air Force installations. There was no attempt to prevent marginally performing technicians nor equipment with minimal capabilities from participating in the program. Both the technicians and equipment were assigned by Air Force on-site management on an availability basis irrespective of expected performance. Therefore, the resulting data reflect a possible wide range of technician and equipment capabilities.

The overall reliability of NDI performed by the Air Force and evaluated in this program, falls below that which has been previously assumed by established guidelines such as MIL-A-83444, "Airplane Damage Tolerance Requirements." The mean probabilities of detecting fatigue cracks in built-up aircraft structure, using typical maintenance inspection techniques and procedures, are at least 25 percent less than the previously assumed values.

Of foremost importance is the realization that the current 90-95 percent reliability criteria (90 percent probability of detection at a 95 percent level of confidence) cannot be attained for any flaw size with typical inspection techniques applied by the average technician. With one exception, the NDI techniques employed in the program demonstrated considerable difficulty achieving a 50 percent probability of detection with 95 percent confidence for 1/2-inch crack sizes. However, the limited use of more advanced, semiautomated eddy current and ultrasonic equipment (incorporated late in the program) indicated that the 90-95 percent reliability criteria may be achievable at crack sizes somewhat smaller than the 1/2-inch measured by this program.

The average capability among both field and depot NDI shops was found to be uniform (therefore predictable), with the exception of one installation. This aspect of uniformity is a strong point which can be used to advantage if changes are incorporated Air Force-wide into the NDI system. Such changes therefore should affect the NDI system uniformly. In addition, future representative measurements of Air Force NDI capability can be achieved by using a smaller sample of installations.

A distinctly higher level of flaw detection success was achieved at one exceptional installation, a depot, especially with the eddy current bolt-hole method. This demonstrated that considerably better performance levels than those generally exhibited are possible. The superior performance at this one installation is attributed solely to individual proficiency. The attributes which produced the superior performance and which can serve as a model in efforts to upgrade overall NDI performance are believed to be the following:

1. NDI operations were conducted within an organization which is exclusively dedicated to nondestructive inspection.
2. A staff of skilled personnel was acquired by a selective process.
3. A form of certification-recertification was performed at periodic intervals.

The major variation in inspection results was found among the individual technicians themselves. There are vast differences in the performance levels of individuals, as evidenced by comparisons of curves plotted for the upper ten percent of technicians with the mean curves for all technicians. The factors which might be expected to have a strong direct bearing on individual NDI performance, such as formal education, technician age, classification, skill level, NDI experience and NDI training, were evaluated and found to have only minimal influence on performance levels. The primary source of variance among individual technicians is believed to be the area of human factors, which should be further investigated.

With the exception of the one depot noted, there were no significant differences between individual installations, nor between individual Commands, nor between field and depot installations. Likewise, there was no significant difference observed between technicians using different manufacturer's equipment.

These general conclusions and other specific conclusions are further discussed in detail in Section XII of this report.

SECTION I. BACKGROUND

Nondestructive inspection (NDI) has, over the past ten years, evolved into a vital part of the management of aircraft fleet maintenance within the Air Force. Nondestructive methods of interrogating parts and assemblies for damage incurred through normal use, environmental exposure and cyclic fatigue are applied to both detect and assess that damage. Predictions of the extent of damage which can be expected with given aircraft missions are now being made on a quantitative basis and NDI is charged with the responsibility of finding existing flaws. Both major scheduled fleet maintenance at the depots and routine maintenance operations at the field level employ specific procedures to seek out flaws before they cause major failures. Additionally, special inspections are performed in response to unanticipated damage which may appear on aircraft in-service.

FLAW DETECTION CRITERIA

The impact of NDI is felt in operations dealing with both aging aircraft and new systems. The drive to extend the service life of aging aircraft beyond the originally planned use period places the burden of proving structural integrity upon NDI. Newer systems are emerging with critical, highly stressed components which are more sensitive to flaws and therefore are requiring periodic NDI to ensure structural integrity throughout their life. In both cases, old and new aircraft, fracture mechanics technology is being applied to quantitatively define damage tolerance limits for given flaw sizes and to establish flaw growth rates under specific service conditions. The capabilities of NDI to detect flaws also must be quantified to allow fracture technology to become practical. As a first step, nondestructive methods applied in production environments have been quantitatively evaluated by several contractors in recent airframe procurement programs, but the need still has remained for evaluation of current in-service NDI maintenance capabilities.

Damage tolerance and structural integrity are treated as the overall guiding concepts in MIL-STD-1530, "Aircraft Structural Integrity Program." Requirements center around airframe design, design analysis and development tests, full-scale testing, force management data, and the force management itself. The possible existence of inherent flaws and the probability of their detection is implicit to all five of these requirements. Design and development functions which interrelate with NDI are treated in MIL-A-83444, "Airplane Damage Tolerance Design Requirements." This specification asserts that flaws are inherent to any material and that designs must account for them. The capabilities of NDI to detect flaws of specific dimensions are assumed possible within the production environment and any analyses which must assume inherent flaw dimensions smaller than the specified values in MIL-A-83444 must incur a demonstration of capabilities to detect those smaller flaws. The B-1 and A-10 programs are examples of demonstrations performed to satisfy the requirements of MIL-A-83444.

In-service flaw detectability assumptions for airframes have also been set forth in MIL-A-83444; however, there have been no measurements made of actual capabilities nor are any demonstrations of in-service detection capabilities required. A baseline is needed to establish experimentally derived values for in-service flaw detection probabilities, much as demonstrations

in the production environment have established a baseline for that condition. This program has filled that need by acquiring and analyzing Air Force field and depot NDI reliability data which establish flaw detection probabilities for a number of operating and environmental parameters. The results are applicable for filling out the spectrum of NDI interrelationships called for in MIL-STD-1530; the force management data package and the force management itself. Application of the results center around the quantification of flaw detectability limits, inspection management within the maintenance environment, and identification of areas for improvement.

NDI RELIABILITY OBJECTIVES

The overriding objective of the program is to determine the existing capability of NDI to detect flaws under field and depot conditions. These capabilities are graphically displayed as detection probabilities relative to flaw size for specific inspection conditions. This information when coupled with appropriate fracture mechanics data such as crack growth rates, allows for quantitative determinations of maintenance inspection intervals. Additionally, the unique, quantified NDI reliability data from this program allow for analyses which point out areas for improvement in operations through efficient selection of NDI methods, and the optimization of human factors in managing NDI personnel. Significant cost savings can be realized by applying quantitatively established NDI data in the maintenance cycle to prevent failures and unnecessary down-time of aircraft. Additionally, NDI functions which are presently specified but have a very low probability of accomplishing their objectives, as viewed in the light of this effort, can be eliminated or changed.

The process of acquiring NDI reliability data has been primarily centered around the performance of flaw search tasks on a number of samples with fatigue cracks. A sufficient number of samples and/or flaw detection attempts are made to establish a statistically adequate volume of data for each selected set of conditions. The philosophy of most test plans is either to select a target flaw size and proceed to determine whether that size can be reliably detected, or to measure detection probabilities for a spectrum of flaw sizes without a commitment to a detection probability at a given flaw size. The B-1 and A-10 demonstration programs were designed to provide evidence that a given flaw size could be detected with a high degree of certainty. A 90% probability of detection at a 95% level of confidence has been established as the criterion for that high degree of certainty. The 90/95 values arose from "B" values established for basic materials property characterizations with test data inherently containing scatter. The generation of NDI reliability data with a spectrum of fatigue crack lengths, on the other hand, has been accomplished for research and technology purposes as NDI inputs to design, fabrication, and maintenance planning tasks.

PRIOR RELIABILITY EFFORTS

Historically, NDI reliability work in the aerospace industry and the Air Force began with a recognized need for such data to interplay with evolving fracture mechanics analyses in the late 1960's. The first detailed investigation was conducted by Packman, et.al., (Reference 1) for the Air Force Materials Laboratory. The objective was to measure flaw detectability for aircraft production parts. A number of programs sponsored by both the Air Force and NASA have been performed since that time, with a diversity of specimen configurations and flaw types employed in the flaw detection tasks. A comprehensive repository of information

acquired from many of these programs was developed and processed for NASA by Yee, et.al., (Reference 2) in 1976. Recent data contributions for the Air Force have been developed by Lord (Reference 3) and Southworth, et.al. (Reference 4), and for NASA by Rummel, et.al., (Reference 5). A program to examine the diverse results from a number of studies which provided nondestructive flaw detection reliability data and to devise a model to translate or interrelate those data was conducted for the Air Force by Chang, et.al., in 1976, (Reference 6).

Initial work on assessing NDI reliability on built-up structure, as contrasted to production part configurations, was conducted as internal research at the Lockheed-Georgia Company beginning in 1971; Project No. 71R2320. Following the failure of an engine pylon on a C-5A, an internal study was also conducted to determine in-service flaw detection probabilities for a pylon truss-to-shroud assembly with fatigue cracks originating at fastener sites in the truss itself. The results of this study are presented in a report by Sproat (Reference 7), which showed that fatigue crack detection probabilities in assembled structure would be generally lower than for comparable flaws in parts or specimens. Full-scale assessment of NDI capabilities from an in-service maintenance standpoint was performed for internal Lockheed research tasks on C-130 center wing boxes which were removed from service, fatigue cycled to induce damage, and tested for residual strength. Results of this work are presented in a Lockheed report by Sproat and Dodd (Reference 8). Two general conclusions were found at that time:

1. Fatigue crack detection probability on structure, by single applications of ultrasonics and eddy-current NDI techniques, is significantly lower than that normally assumed for most fail-safe and monolithic slow crack growth airframe designs.

2. Redundant inspections using multiple applications of one technique or a mixture of techniques can be employed to yield the detection levels required for most slow crack growth and fail-safe designs if the inspection conditions were similar to those experienced in this independent research program. The influences of other factors on detection reliability were not evaluated.

The experimental approach to provide data for answering the numerous questions regarding the nondestructive maintenance inspection processes were formulated after careful analysis of the results of the above two efforts.

SECTION II. PROGRAM PLANNING

The Air Force Logistics Command's Material Management organization is charged with the responsibility to oversee NDI operations from a technical standpoint, in both depot and field locations. Increasing demands for the use of NDI in on-going maintenance functions, coupled with the drive to employ NDI as a functional tool within the scope of MIL-A-83444 philosophy, brought about the need to quantify in-service capabilities. With the recognized need and technical responsibility, the AFLC proceeded to establish a three-phase effort to measure NDI capabilities on-site within the field and depot facilities. A statement of work was defined in May 1974 which established technical objectives for; 1) detailed planning, 2) implementation of data acquisition, and 3) flaw size confirmation/data analysis phases of a comprehensive program. The Planning phase commenced in June 1974 with the rudiments of a detailed experimental approach outlined in the "Phase I Mid-Term Report", August 1974 (Reference 9).

This mid-term report during the Planning phase was intended to allow for a critical review of: (1) the types of specimens (structure) and NDI techniques under consideration, (2) the program constraints and technical limitations, and (3) the design of a detailed test plan to allow the statistical formulation of technically valid conclusions.

FLAWED STRUCTURE

The structural samples or specimens recommended at that time were identified as Type A, C-130 center wing box section with surface fatigue cracks radiating from fastener sites; Type B, C-130 center wing box plank segments with surface fatigue cracks like Type A; and Type C, titanium straps with through-the-thickness edge fatigue cracks. Types A and B were derived from structure which had undergone in-service fatigue damage, extended fatigue damage in a test jig and failed under a static load applied to determine residual strength. Documented test history and flaw data on these items are presented in Reference 10. These items also were the structure samples used in the independent research work described in Reference 8. Type C structure samples were those used in the C-5A pylon aft truss NDI evaluation effort described in Reference 7. The parameters used in generating fatigue cracks in these samples are documented in Reference 11. Photos of these structure samples are presented in Figures 3-4 through 3-9, and complete descriptions are provided in Section III of this report.

ORIGINAL CONSTRAINTS

Program constraints, as viewed at that time were primarily keyed to the availability of suitable structure with an adequate number of flaws of varying sizes. To establish curves of flaw detection probabilities with enough data for statistically sound evidence, the flaw population and the number of NDI attempts should be sufficiently large. The Phase I Mid-Term report proposed the following data acquisition approach:

1. An anticipated elapsed time of 5 to 8 hours per individual per NDI technique on A and C specimen types. Two inspectors could simultaneously interrogate specimen Types A and C while others perform on specimen Type B. The following table (Figure 2-1) denotes the assignment of six inspectors for a 12-day period of work on specimens following an orientation period of 1 day.

2. The total elapsed time per location (with six inspectors) required for set-up, data acquisition, and tear-down was anticipated to be 15 working days.

3. The technical limitations were primarily involved with the magnitude of the data sample. The specimen Type A contained 17 fatigue cracks in the 0.1" long size category, 5 cracks in the 0.2" long size category, etc. If six individuals took part in the effort at each location, the crack sample in the 0.1" long category for specimen Type A would be 6 x 17 = 102, for example. A sample size of 30 would be sufficient to attach statistical significance. The available cracks in the 0.1" long category for the Type A specimen was therefore quite adequate. The available cracks in the 0.3" through 0.6" category were, however, insufficient to establish statistical significance to data in those size categories for individual locations. Pooling data from several locations would allow for statistical significance in treating results among groups (locations).

4. The available fatigue crack population for specimen Type B was adequate to attach additional significance within groups for each flaw size category through 0.6" at each location or base. Specimen Type C allowed for flexibility in the population for sites ranging from 0.05" to 0.30". Statistical significance for results on flaw size ranges within groups would be possible for the Type C specimens.

5. The controlled and uncontrolled variables, as technical limits, were additional program constraints. The controlled variables were:

   a. the NDI methods (eddy current, radiography, ultrasonics, and penetrant)

   b. use or omission of detailed procedures and calibration standards

   c. specimen configuration

      (1) position (overhead, vertical, etc.)

      (2) access

      (3) flaw size population

      (4) flaw density (ratio of flawed to unflawed area)

	M	T	W	T	F	M	T	W	T	F	M	T	W	T	F
Inspector No. \ Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
H		C^U	C^P	A^U	A^E			B^E	B^E			B^X	B^X		
I		A^U	A^E	C^U	C^P					B^X	B^X	B^E	B^E		
J		B^X	B^X			C^U	C^P	A^U	A^E	B^E	B^E				
K		B^E	B^E	B^X	B^X	A^U	A^E	C^U	C^P						
L						B^E	B^E	B^X	B^X	C^U	C^P	A^U	A^E		
M				B^E	B^E	B^X	B^X			A^U	A^E	C^U	C^P		

A = Large Wing Box Section (U, E) - 1 Day/Inspection = 2 days

B = Small Wing Box Pieces (E, X) - 2 Days/Inspection = 4 days

C = Ti Specimens (U, P) - (U = 8 hrs, P = 8 hrs/Inspection) = 2 days

U = Ultrasonic

BH = Bolt Hole Eddy Current

E = Eddy Current

X = X-ray

P = Penetrant

Figure 2-1. Activity Sequence at a Base

(5) specimen complexity (shape and number of elements)

(6) specimen randomness (cues for probable defect location)

(7) flaw character

The uncontrolled variables included:

a. environment

b. human physiological response

c. attitude (psychological)

d. inspection pace (with upper limit)

e. disruptive factors

f. personnel and equipment

Some of the variables were quantitative while others such as the inspector's attitude were not, thus introducing unknowns into the results. Approaches used to minimize the uncertainty of the test results are described in the final detailed Test Plan (Reference 10).

ORIGINAL TEST PLAN

The original program, as envisioned in August 1974, was designed to answer the following questions:

1. What is the relative effectiveness of conventional NDI methods applied to structure, i.e., flaw detection probabilities relative to radiographic, ultrasonic, eddy current, and penetrant inspections?

2. What is the Air Force field and depot capability in NDI? More specifically, what are the probabilities of flaw detection in structure by Air Force personnel and equipment?

3. What differences exist in NDI capabilities from base to base, if any?

4. How effective are 7 Level Air Force NDI personnel in devising NDI procedures?

5. What is the range of individual capabilities among all groups (all bases) and within each group (base)? In other words, what is the scatter factor attributed to individual differences and to differences between bases?

The answers to these questions were to be provided by statistical analysis of the data using flaw detection results as a measure of performance. The nucleus of the data presentations were planned to be graphic plots of detection probabilities relative to flaw length; with confidence limits determined by assuming a Gaussian scatter of points. Tests for significance

of variables were to be performed by a covariance technique which accommodates missing data in a matrix of variable combinations. Details on the development of the graphic plots and the analysis of covariance are provided in Section IX and in the Test Plan (Reference 10).

STEERING COMMITTEE GUIDANCE

On 12-13 November 1974, a Steering Committee, consisting of some of the most knowledgeable experts in this area of technology from both government and industry, was assembled by the Air Force to critically review the original Test Plan which was developed for the Phase I Mid-Term report. The following basic recommendations were made by that Committee:

1. Increase the total number of flaws and types of structure.
2. Provide a more comprehensive scope of data acquisition through the Air Force.
3. Prepare a briefing to introduce the program content and scope to the Air Force Logistics Command Management and Engineering personnel.
4. Prepare a detailed Test Plan with updated content on structure samples and base visits for Steering Committee review by March 1975.
5. Delete the option for on-site NDI procedures development.
6. Develop an orientation briefing to familiarize participants with the purpose, scope and mechanics of the program.

The first item above impacted the total effort by increasing the total number of structure samples. No additional C-130 wing boxes with sufficient quantities of fatigue cracks were readily available. Additional samples were acquired from the Air Force through the efforts of Capt. W. Lundy at Oklahoma City ALC and A. Rogel at Sacramento ALC. A segment of a KC-135 center wing lower plank with suspected fatigue cracks at fastener sites and nine (9) pieces of F-104 forged wing fittings with suspected fatigue cracks at fastener sites were obtained. Automatic eddy current bolt-hole NDI strip chart records accompanied the F-104 wing fittings. The search for suitable pieces of the C-5A fatigue article X998 wing assembly was not fruitful.* Another C-5A test article, however, was located and found acceptable: a C-5A configured wing spar web-to-cap box beam test article. A detailed report for fatigue damage identification is contained in Reference 11. The KC-135 sample obtained was identified as Type D, the F-104 fittings as Type E, and the C-5A box beam specimen as Type F.

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*It became clearly evident, in attempts to expand the structure sample size for the program, that representative fatigue damaged structure with a suitable population of flaws ranging over a spectrum of lengths is very difficult to obtain. Therefore, the bulk of the structure samples used were those which were recommended in the Phase I Mid-Term Report on this program.

The scope of data acquisition, Item 2, was expanded from an original plan to visit one base in each major command; Military Airlift Command, Tactical Air Command, Strategic Air Command and Air Training Command, to four bases each. A full spectrum of capabilities at the field level, plus visits to the five depots, was expected to provide a more representative measure of Air Force capabilities in NDI. The remaining action items were completed as scheduled, with the final Detailed Test Plan submitted for review by the Steering Committee in March 1975. The final approved version of this document was published in July 1975 (Reference 10).

SECTION III. PROGRAM TECHNICAL APPROACH

The primary approach to the program as approved in the final Test Plan (Reference 10) is as follows:

a. Select representative structure with known defects which can be routinely inspected by existing NDI Air Force depot and field installations. The numbers and sizes of defects shall be adequate for statistical analyses of results.

b. Subject the structure to routine NDI at a full spectrum of Air Force depot and field installations with a representative sample of NDI technicians and inspection conditions.

c. Examine the results of the NDI in terms of flaw detection probabilities as a function of flaw size on a statistical basis. The major evaluation parameters shall be (1) technician skill level, (2) depot versus base capabilities, (3) NDI method used, and (4) type of structure. Analyses shall be performed to determine the influence of these parameters on flaw detection probabilities.

The Detailed Test Plan was designed to provide the details to be used in acquiring and alyzing the NDI data. It was the end result of the program planning which included following tasks:

a. Design, fabricate, and/or purchase hardware and support equipment to transport and maintain field operations required for on-site evaluations of NDI at selected Air Force installations.

b. Establish a complete program of participant orientation, procedures for performing the NDI, and clear instructions for reporting defect finds.

c. Devise a scheme for transferring raw data on NDI test results, NDI personnel profiles, base NDI equipment evaluation, environmental factors surrounding tests at the Air Force bases, individual equipment settings used by each technician on each NDI performed, and daily log entries at each base.

d. Develop a method of data analysis to statistically evaluate NDI effectiveness in terms of detection probabilities as a function of flaw size at 50%, 90%, 95%, and 99% confidence levels. The major parameters to be addressed in this evaluation are: (1) field versus depot locations, (2) training and proficiency of NDI personnel, (3) the NDI methods employed, and (4) the type of structure used in the test.

e. Devise procedures to set up structure samples into typical configurations encountered for NDI at the depot and field installations as well as structure sample cleaning and processing for re-use.

f. Develop means of reporting the findings to facilitate Air Force planning of (1) inspection scheduling, (2) use of equipment, (3) training and placement of NDI personnel, and (4) damage-tolerant design and risk analysis.

The approach took full advantage of using actual aircraft structure* with fatigue cracks as samples for NDI. These structure samples were presented to the NDI technicians in settings which very closely represented those encountered in routine field and depot operations. Some samples were placed in an overhead position to simulate NDI on a wing lower surface. Other configurations included face-up positions and vertical-plane positions, typical of a full range of structure.

The NDI technicians, after an orientation briefing, were assigned specific NDI tasks on these samples as called out in the procedures designed for each task. Results of this NDI were recorded and sent to Lockheed, along with accompanying parametric data. A cumulative analysis of data, by regression and covariance, were performed as the data became available. Both raw data and analyzed results were provided to the AFLC as soon as available.

GENERAL OVERVIEW

Tradeoffs among cost, availability of suitable structure, and selection of the number of test sites and participants were examined. Ideally, each factor which contributes to the results should be controlled independently on a strictly quantitative basis. It was also desirable to acquire a large number, 80 to 100 points, of data under each controlled set of conditions. The study of tradeoffs showed that practical considerations provided approximations to the best case. Therefore, the following plan was devised:

a. Six different types of representative aircraft structure to be inspected at each installation. A description of each and the associated NDI to be performed is compiled in Figure 3-1. Figure 3-2 lists the originally estimated length of flaws in each structure. The aggregate length distribution is provided in Figure 3-3.

b. An average of 15 participants at each Air Logistics Center and 6 participants at each field level base within the Commands to be visited were desired depending on availability.

c. Four major test variables will be controlled or directly observed: (1) field or depot location, (2) NDI method, (3) proficiency of inspectors, and (4) type of structure with accompanying flaw sizes. The following ancillary factors will be recorded: (5) NDI equipment condition, (6) environment, and (7) position of structure (overhead and below for eddy-current surface scans).

*The size and number of flaws cataloged for data acquisition was originally based on NDI and close visual inspection on assembled structure. The actual features and total content of flaws in the structure samples are provided in the teardown data; Section VII.

Specimen Type		Inspection Methods					
		Ultrasonic Shear Wave	Eddy-Current Surface Scan	Eddy-Current Bolt Hole Scan Manual	Eddy-Current Bolt Hole Scan - Automatic*	Penetrant*	Radiography Assembled
Ltr	Description	1	2	3	4	5	6
A	C-130 Wing Box	X	X				
B	C-130 Wing Panels		X				X
C	Ti Riser Spec.	X				X	
D	KC-135 Wing Cover Plks	X		X	X		
E	F-104 Fitting			X	X		
F	C-5A Box Beam Spec.	X		X	X		

*Where facilities permit.

Figure 3-1. Combinations of Specimens and Inspection Methods

	Structure Sample						Summary	
Crack Length	Type A	Type B	Type C	Type D	Type E	Type F	Crack Length	No. Flaws
.010				2-5	1-47			
.010				2-10	1-27		.010	5
.010					2-7			
.015						6-66		
.015						6-67	.015	3
.015						6-77		
.020			44	2-12	2-36	1-66	.020	4
.030				1-8	2-6	1-14		
.030				1-24	2-44	5-26		
.030				1-48		5-68		
.030				1-69		5-81	.030	14
.030						5-82		
.030						5-84		
.030						6-70		
.030						6-72		
.040				1-34	2-20	1-15		
.040				1-60	2-84	1-69		
.040				2-3		2-8	.040	10
.040						2-14		
.040						2A18		
.041						1-9	.041	1
.050					2-23	1-11		
.050					2-26	1-69		
.050					2-55	1-71		
.050					2-63	1-73	.050	11
.050						5-65		
.050						6-15		
.050						6-65		
.060			15		2-54	1-11		
.060			15		2-67	1-79		
.060			39			2-26		
.060			40			2-82	0.60	15
.060			42			2A21		
.060			44			6-7[illegible]		
.060			45					

Figure 3-2. Flaws in Structure Samples Identified by Number

Crack Length	Structure Sample						Summary	
	Type A	Type B	Type C	Type D	Type E	Type F	Crack Length	No. Flaws
.070			40		1-49	1-9	.070	6
.070						1-24		
.070						1-66		
.070						1-79		
.080	75	112/8b	43		1-23	1A22	.080	6
.080					2-68			
.090	77a		37		1-22	1-79	.090	8
.090	122		43			6-71		
.090			45					
.10	121	111/V-2a	14		1-8	1-79	.10	17
.10	132	101/29b	27		1-22	2-20		
.10	75	112/12a	37		1-28			
.10			46		2-80			
.10			46					
.11	14	111/25a				2-18	.11	5
.11	27					5-10		
.12	76b	112/6b	48		2-69	1A21	.12	9
.12	80	301/1a	51					
.12		301/2b						
.13	79d	302/36a				1-23	.13	7
.13	125					1-69		
.13	77b					2-72		
.14	133	102/27a	34		1-19		.14	7
.14			34					
.14			48					
.14			54					
.15	129	111/29b	51			1-23	.15	7
.15		111/U-1b						
.15		101/34b						
.15		112/6c						
.16	7	301/4a					.16	5
.16	78							
.16	131							
.16	9b							

Figure 3-2. Flaws in Structure Samples Identified by Number (continued)

Crack Length	Structure Sample						Summary	
	Type A	Type B	Type C	Type D	Type E	Type F	Crack Length	No. Flaws
.17 .17 .17	8a	112/9b 141/31b	41 41 54			2-24	.17	7
.18 .18		111/U-1A	58 58		1-14	1-69 1A1	.18	6
.19 .19	10d 130	302/35a	47 47			1A1	.19	6
.20 .20 .20		301/3a 301/5a	26 26 59		1-32		.20	6
.21 .21 .21 .21	8c 76a 81b 123	141/27a	50 55 55 59				.21	9
.22 .22 .22 .22 .22	9a 11b		8 29 50 52 52				.22	7
.23 .23 .23	8b 12b 79a	111/8b 112/26a 301/3b	8 53 53			6-73	.23	10
.24	11a		29				.24	2
.25 .25	81a		57 57		1-1		.25	3
.26		111/25b					.26	1
.27 .27		102/28b	1 60		2-3		.27	4
.28 .28		112/9a	1 60				.28	3
.29	11a	112/26b					.29	2
.30 .30		111/23a 112/8a					.30	2

Figure 3-2. Flaws in Structure Samples Identified by Number (continued)

Crack Length	Structure Sample						Summary	
	Type A	Type B	Type C	Type D	Type E	Type F	Crack Length	No. Flaws
.32		133/11b					.32	1
.33 .33 .33 .33	124	101/30a 101/V-1a 134/12a 142/14a					.33	5
.34	20						.34	1
.35 .35		101/30b 141/13b					.35	2
.36 .36		112/6a 141/31a					.36	2
.37 .37		112/6d 141/27b				6-84	.37	3
.39	4b						.39	1
.46	6a	102/28a					.46	1
.52 .52	4a 5a						.52	2
.57 .57	102a 6b						.57	2
.58 .58		141/13a 111/8a					.58	2
.60		101/V-1b					.60	1
.63		133/11a					.63	1
.65		142/14b					.65	1
.66	5b	134/12b					.66	2
.72		112/7a					.72	1
.75		112/7b					.75	1
1.05	4c						1.05	1

Figure 3-2. Flaws in Structure Samples Identified by Number (continued)

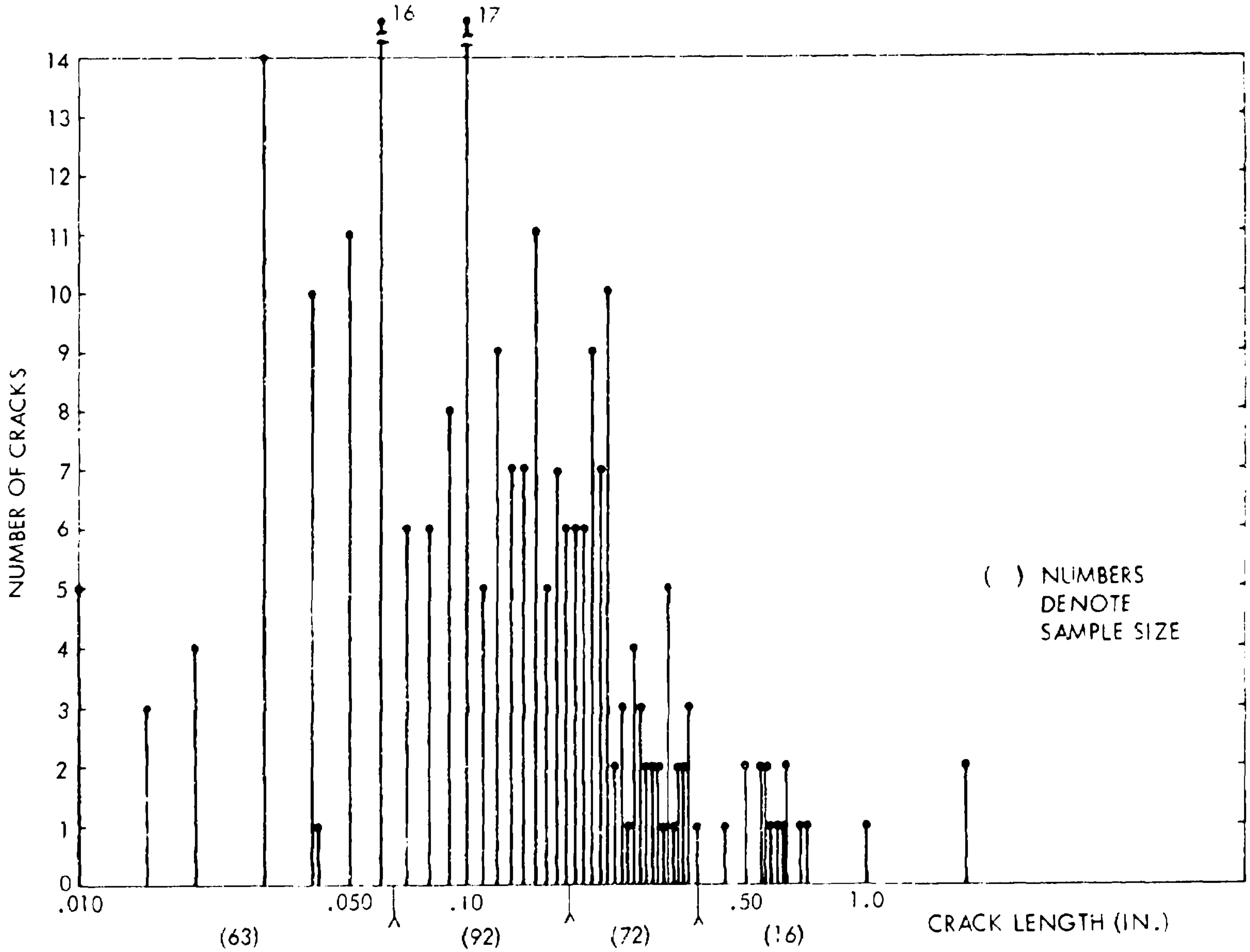


Figure 3-3. Aggregate Crack Length Distribution - All Structure

The combination of all flaw detection opportunities at all bases was expected to yield approximately 46,000 individual measurements. The implementation of these measurements is addressed in subsequent sections of this report.

STRUCTURE SAMPLES

The six types of representative structure compiled in Figure 3-1 are shown in Figures 3-4 through 3-9. They are as follows:

Sample Type	Description
A	C-130 center wing box, intact 5-foot segment
B	C-130 center wing box lower-surface segments
C	Simulated titanium wing risers mounted inside Sample A
D	Two sections of KC-135 center wing lower plank
E	F-104 wing fitting segments
F	C-5 wing spar cap/web test assembly (box beam)

Type A Structure

The intact segment of a C-130 wing box contains known fatigue cracks in the lower surface. Typically, chordwise cracks are located at fastener sites, cutouts and drain holes. The wing box had received service induced fatigue damage, was removed from service, and cyclically loaded in a test jig to further induce damage prior to residual strength testing. The lower surface was stripped of paint for visual crack detection and measurement during tests. After conclusion of the residual strength test, the structure was employed as a test specimen at Lockheed for internal nondestructive inspection reliability programs. A surface finish was reapplied in the form of an epoxy primer and a single coat of polyurethane paint. The Type A structure was mounted on a dolly with the lower surface facing upward for NDI accessibility in this effort.

Type B Structure

Twelve segments of a C-130 center wing lower surface comprise the Type B items. The history of these items is identical to the Type A structure and they have been flame cut for removal from the parent structure. Conductivity readings were taken on suspected heat damaged areas to define the extent of any damage. The edges were subsequently trimmed from the segments as required to allow only undamaged material to remain. Fatigue and residual strength load histories on Types A and B structure are available in Lockheed-Georgia Report ER 1178. "C-130, Results of Center Wing Residual Strength and Crack Propagation Test Programs."

Type C Structure

These were edge-fatigue-cracked elements which simulated a portion of the C-5A pylon aft trusses. Both aluminum and titanium elements were produced in 1972 to assess C-5A pylon inspection reliability. Fatigue loads on these items are recorded in Lockheed Laboratory

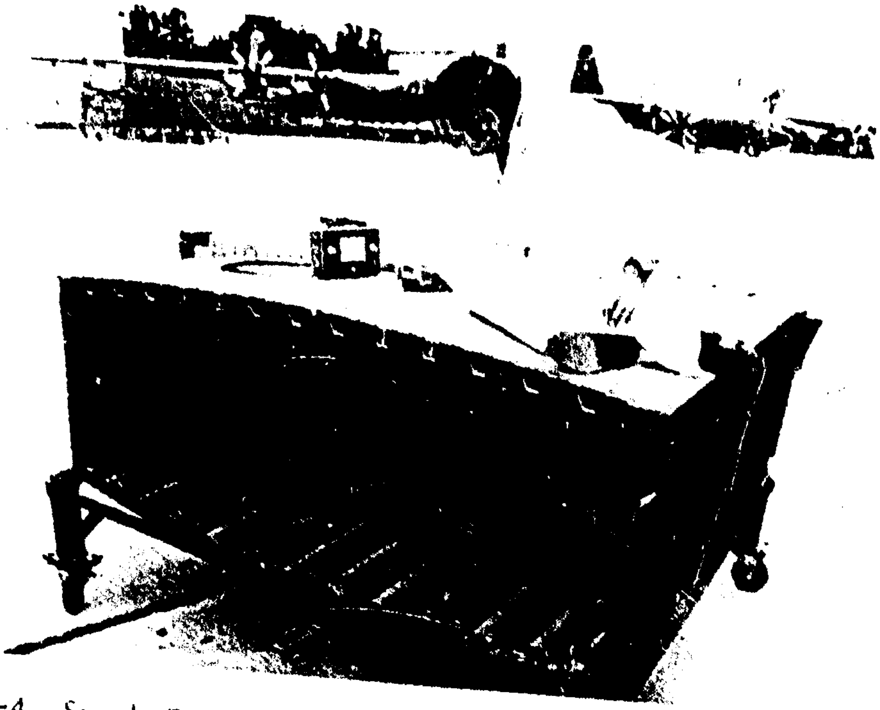


Figure 3-4. Sample Type A - C-130 Center Wing Box, Intact 5-foot Segment

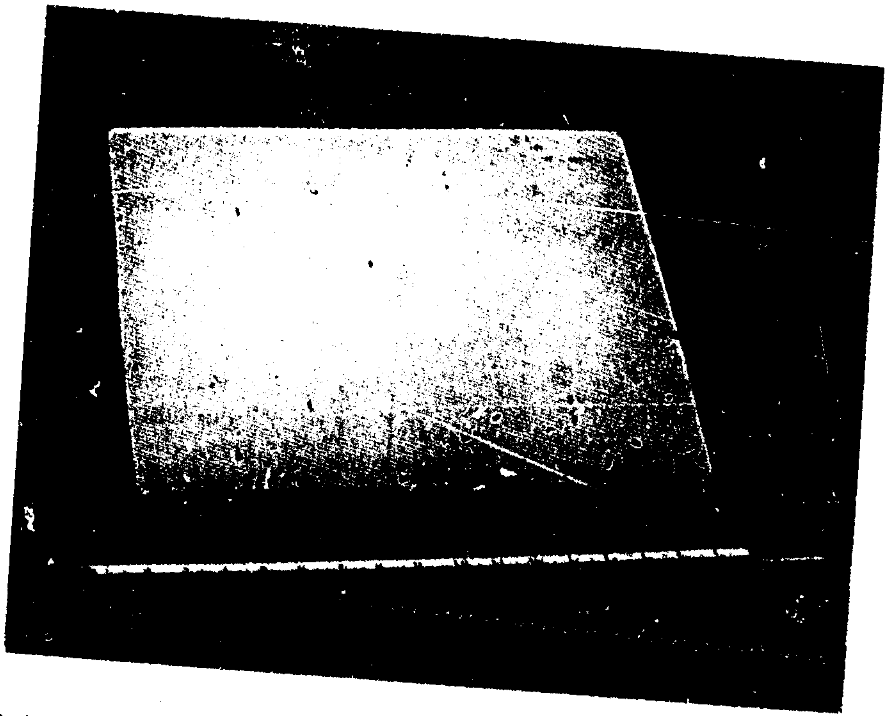


Figure 3-5. Sample Type B - C-130 Center Wing Box Lower-Surface Segments

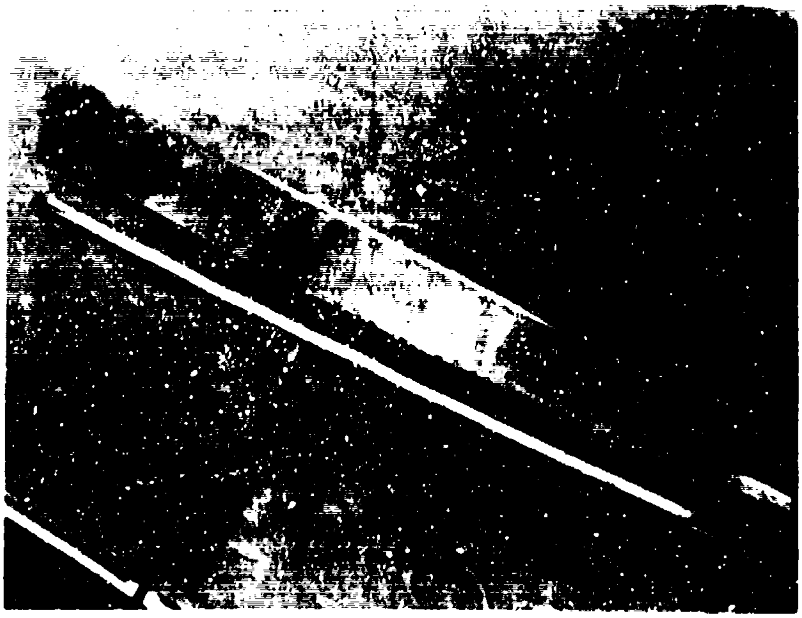


Figure 3-6. Sample Type C - Simulated Titanium Wing Risers

Figure 3-7. Sample Type D - Two Sections of KC-135 Center Wing Lower Plank

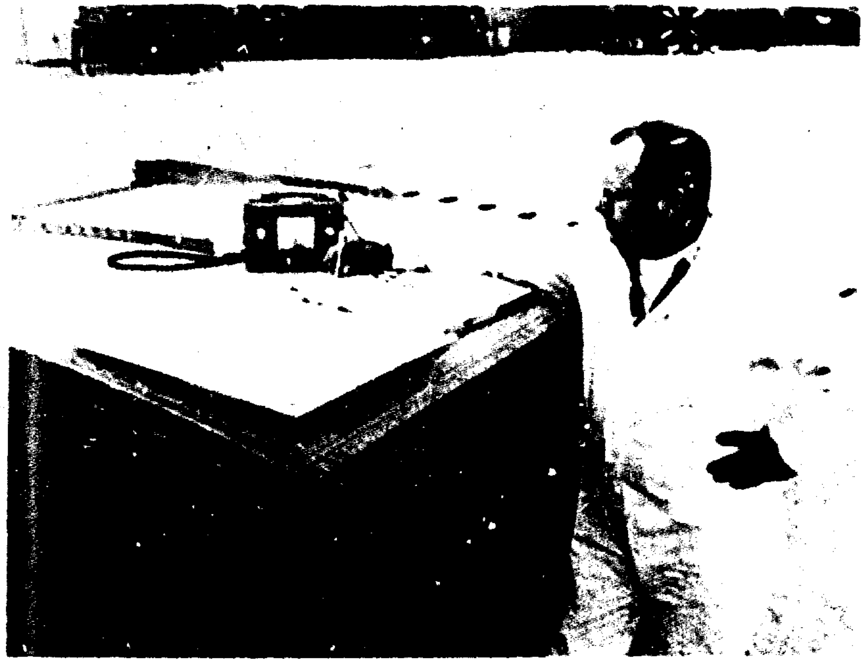


Figure 3-8. Sample Type E - F-104 Wing Fitting Segments

Figure 3-9. Sample Type F - C-5 Wing Spar Cap/Web Test Assembly (Box Beam)

Data Records A364880-A364882. It was planned to use aluminum elements in this program, but difficulties with obtaining consistent penetrant indications eliminated further consideration of their use. The inconsistent penetrant indications were attributed to a build up of oxidation in the tight fatigue cracks to the point of excluding the penetrant in some cases. This effect was not observed with the titanium elements in over fifty (50) penetrant inspection trials prior to including them in this program.

These elements were nested into an open end of the Type A structure for inspection to simulate internal skin risers. Removal and reinstallations for repeated penetrant washout between penetrant NDI applications were possible with this arrangement.

Type D Structure

This item was two sections of KC-135 center wing lower surface with fatigue cracks at fastener sites. The finish had been stripped and surfaces caustic etched when received at Lockheed. It was subsequently coated with a corrosion inhibiting primer.

Type E Structure

These items were bare segments of F-104 wing fittings with service-induced fatigue cracks at fastener holes. The segments were attached to cover plates to provide a layered stack-up typical of multi-element joints.

Type F Structure

This structure was composed of a box beam test specimen designed to represent the C-5A wing mid-beam lower spar cap-to-web assembly joints and mid-beam web-to-stiffener attachments. The box beam had been fatigue tested to evaluate three fastener systems by loading for 147,000 cyclic test hours. Fatigue cracks were generated at some fastener sites. This structure was mounted on a dolly for handling. The fatigue history of the box beam is described in Lockheed Report LG74ER0022.

PROCEDURES

Complete NDI procedures were formulated in the -36 Tech Order format per MIL-M-38780A for each NDI method as applied to each structure type. The procedures included the necessary operating parameters and equipment calibration details. A validation run on each procedure was conducted at Lockheed to ensure compatibility with the program objectives and realistic NDI operating practices at the field and depot. The entire procedures for this effort are provided in the Test Plan (Reference 10).

NDI EQUIPMENT

Plans were to use the existing base NDI equipment at each installation. This was to provide an indication of equipment condition and its affect on total NDI reliability wherever possible. Checks on the condition and status of equipment were handled as part of the essential data to be compiled at Lockheed. Calibration standards for ultrasonic and eddy current procedures

were furnished. Radiography was characterized by a step wedge which was x-rayed at two exposures to develop log relative exposure curves for the particular equipment. Backup ultrasonic, eddy current, and penetrant equipment was maintained in the transport trailer for cases where no equipment was locally available to dedicate to this effort.

FIELD AND DEPOT DATA ACQUISITION

The structure samples were transported to the selected Air Force installations in a utility trailer specifically built for this purpose. The trailer also served as an object on which to mount Type B structure to perform radiographic and eddy current NDI. The trailer and tow vehicle are depicted in Figure 3-10. A pickup truck was used for both transportation of the Lockheed engineer (who remained with the program throughout to provide overall coordination and direction) and trailer towing to the various locations.

On arrival at each base, participants were selected at random, given an orientation briefing and assigned the NDI tasks. Data from the NDI tasks (structure sample inspections) and accompanying evaluations performed by the Lockheed engineer were then compiled and sent to Lockheed. The structure samples subsequently were loaded and operations moved to the next participating base. The following narrative is presented to describe each of the data acquisition steps in detail.

1. Selection of Participants

A representative cross-section of NDI technicians were selected whenever possible with regard to training, skill level, and background. However, some bases had limited numbers of personnel, and the alternative was to obtain data in sufficient quantities at each base by requesting participation from all available NDI technicians. Other bases had more personnel than could be reasonably assigned to this program. For such cases, prospective candidates were selected at random. This was accomplished by assigning identification numbers serially and selections made from a table of random numbers. For example, if there was a need for 10 eddy current NDI technicians but there are 30 available, identification numbers were assigned in sequence from 1 to 30 and the ten selections made from the first ten numbers in a random sequence of numbers from 1 to 30. The selected personnel were then scheduled for the orientation briefing.

2. Orientation

An orientation for instruction and information purposes was prepared in a narrative which was keyed to 35mm slides for an audio/visual presentation, providing consistent instruction throughout the data acquisition effort. Back-projected images were presented on a screen with the device shown in Figure 3-11, which contained a tape replay mechanism for the narration and automatic slide advance. The complete orientation is presented in the Test Plan (Reference 10). Scheduling and assignments were performed at the conclusion of the orientation briefing.

3. Scheduling

A matrix of NDI tasks and personnel, referenced to the structure sample types and NDI method, is presented in Figure 3-12. This matrix was designed to ensure

Figure 3-10. Equipment Trailer and Tow Vehicle

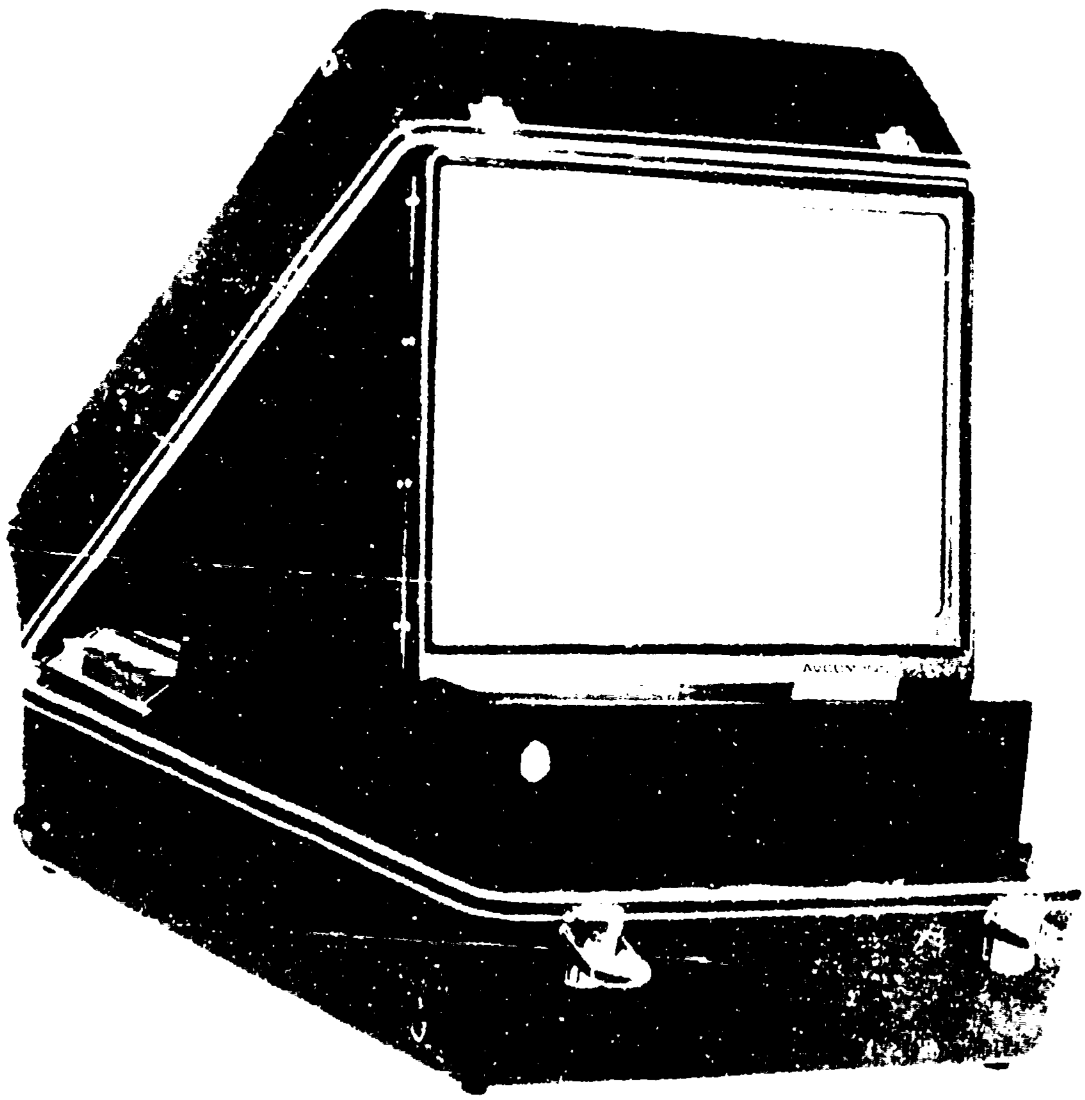


Figure 3-11. Audio-Visual Equipment for Orientation

WEEK	DAY	A_{UT}	A_{ET}	B_{RT}	B_{ETUN}	B_{ETOH}	C_{UT}	C_{PT}	D_{UT}	D_{ETBH}	E_{ETBH}	F_{UT}	F_{ETBH}
		TYPE OF STRUCTURE SAMPLE AND INSPECTION											
I	1.		E1	R 1/2	E2		U1			E3	E3	U2	E4
	2.	U1		(Read)	E1	E2		P1	U2	E4	E4		E3
	3.		E3	R 3/4	E4		U2			E1	E1	U1	E2
	4.	U2		(Read)	E3	E4		P2	U1	E2	E2		E1
	5.		E5	R 5/6	E6		U3			E7	E7	U4	E8
II	6.	U3		(Read)	E5	E6		P3	U4	E8	E8		E7
	7.		E7	R 7/8	E8		U4			E5	E5	U3	E6
	8.	U4		(Read)	E7	E8		P4	U3	E6	E6		E5
	9.		E9	R 9/10	E10		U5			E11	E11	U6	E12
	10.	U5		(Read)	E9	E10		P5	U6	E12	E12		E11
III	11.		E11	R 11/12	E12		U6			E9	E9	U5	E10
	12.	U6		(Read)	E11	E12		P6	U5	E10	E10		E9
	13.		E13	R 13/14	E14		U7			E15	E15	U8	E16
	14.	U7		(Read)	E13	E14		P7	U8	E16	E16		E15
	15.		E15	R 15/16	E16		U8			E13	E13	U7	E14
IV	16.	U8		(Read)	E15	E16		P8	U7	E14	E14		E13
	17.		E17	R 17/18	E18		U9			E19	E19	U10	E20
	18.	U9		(Read)	E17	E18		P9	U10	E20	E20		E19
	19.		E19	R 19/20	E20		U10			E17	E17	U9	E18
	20.	U10		(Read)	E19	E20		P10	U9	E18	E18		E17

LEGEND:

A, B, C, ... F	Structure Sample Type
UT	Ultrasonic inspection
ET	Eddy Current Inspection (UN-underneath; OH-overhead; BH-Bolt Hole)
RT	Radiography
PT	Penetrant Inspection
U1, U2, ... U10	Ultrasonic Technician
E1, E2, ... E20	Eddy Current Technicians

Figure 3-12. Matrix of NDI Task Assignments used with Maximum Rate of Data Acquisition

compatibility of simultaneous inspections on the structure samples and to optimize scheduling efficiency. The primary function of the matrix was for coordination by the Lockheed engineer and local base management.

4. Inspections

The NDI was performed under the guidance and coordination of the accompanying Lockheed engineer. A minimum amount of individual instruction beyond the orientation was occasionally required in special cases, but the goal was to avoid assistance which could bias results. The NDI procedures were supplied together with general inspection information as a manual for the inspections in this program. Participants were given ample opportunity to read the procedures and ask questions before proceeding.

5. Sample Cleaning and Recycle

Marks on structure samples to denote detected cracks were made with grease pencils by the technician and removed with solvent after transcribing to the data sheets. Penetrant residing in Type C structure samples after each inspection was removed by ultrasonic cleaning in an isopropyl alcohol bath. Both of these cleaning operations were performed by the Lockheed engineer. Fifty cycles of penetrant application and removal on a Type C sample had been previously conducted to ensure that no biasing effects are introduced by repeated cleaning. Results of this test showed no significant changes for penetrant response, yet the cleaning is effective for penetrant removal.

The routine cleaning required to perform the penetrant NDI was performed by the technician. Penetrant NDI was planned on the Type C samples to follow ultrasonic NDI which left a viscous coupling medium on the surfaces. The residual couplant on the surfaces inhibited effective penetrant response to the fatigue cracks unless proper cleaning preceded the penetrant application. This sequence of NDI methods was intended for the purpose of testing the NDI technician's overall ability to perform tasks according to the procedures.

6. Data Transmittal

The raw data was transmitted by mail or carrier from the field to Lockheed. Upon receipt at Lockheed, the flaw indications were systemized for data processing in the format presented in Figure 3-13. Technician Profiles, Equipment Evaluations, and Environment Reports were filed by Air Force categories in their original narrative form.

All raw data, classified by location at which they were acquired, were submitted to the Air Force Logistics Command Program Monitor both in the reports of data analysis and as requested on occasion throughout the process of data acquisition. The purpose in maintaining the raw data is for future analyses by different methods or for different objectives than those set forth in this program.

Sample Type/NDI Method										
Flaw ID	Flaw Size	Technician Identification							S/n	%
S/N										
%										
F										

S = Total Finds

n = Number of Inspections

N = Number of Flaws

F = Total False Calls

Figure 3-13. Basic Data Summary Format

7. Data Reporting

All raw data were cataloged and available to the Air Logistics Command throughout the period of base visits. Processed flaw detection data, incrementally updated after each base visit, was reported to the Air Logistics Command at the update times. The final report for the data acquisition and analysis was planned to contain the following:

a. Histograms of four flaw size ranges versus mean detection probabilities and probabilities at the 50%, 90%, and 99% lower confidence levels. The histograms being classified by the primary variables of depot or field NDI, technician grade level, NDI method, and type of structure.

b. Tests for the significance of field or depot site, NDI technician, NDI method, and flaw size influences on detection probabilities at a 90% confidence level.

c. A compilation of non-numerical data from the forms on Technician Profiles, Equipment Evaluations, Environment Reports, and Daily Logs.

ANALYSIS OF RESULTS

The data acquired in this program were statistically evaluated to yield both graphic presentations of detection probabilities with regard to flaw parameters, for given variables, and tests for significance among variables. Rather than develop a description of the analysis here, the reader is referred to Section IX, Analysis Methodology.

SECTION IV. DATA ACQUISITION

After preparation of all structure samples, inspection procedures, data sheets and support fixtures and equipment, a "Dry Run" of program logistics and data acquisition was conducted at the 4950th Air Base Wing, Wright-Patterson Air Force Base, Ohio, during 16-26 June 1975. Everything necessary for the field data collection phase of the program was transported in a specially-built 16' utility trailer. Major items included the structure samples, two 2-drawer file cabinets (with a specially-constructed top so that a desk could be assembled), three 6' tables, 6 folding chairs, 2 bulletin boards, 1 ultrasonic cleaner (for cleaning specimens after penetrant inspection), the inspection procedures and data sheets, and miscellaneous markers, tablets, pencils, and other supplies.

Wright-Patterson Air Force Base

The program "Dry Run" was set up at Wright-Patterson Air Force Base in a large hanger bay. Program briefings were given to management personnel and to the NDI technicians who were to participate in the program. Both briefings were delivered by use of the desk-top slide projector (back projector) that contained a cassette tape player and its own screen (see Figure 3-11). A cassette tape was used to make the oral part of the presentation. This tape was keyed with an inaudible signal that signalled the machine to change slides at the proper time during the presentation. This approach was taken so that all briefings given during the program would be identical, thus avoiding a potential bias in attitude and understanding.

The management briefing, approximately 20 minutes long, provided a description of the program and its goals and a discussion of associated engineering and scientific technologies. The technician briefing, also about 20 minutes long, described the program and informed the technicians what they were to do in the program and how to complete the required data sheets.

After the equipment was set up and suitably arranged and the briefings were completed, the participating technicians were given their assignments. When an assigned inspection task was completed and the detected flaws were properly recorded on the data sheets, the technician was given another NDI assignment. This procedure was continued as long as the technician was available to the program or until he had completed all assignments in the program.

During the stay at Wright-Patterson Air Force Base, many Air Force scientists and engineers visited the area to observe the program as it was being conducted. Comments and suggestions for program improvement were solicited from many of these knowledgeable observers. The program progressed well and was completed on schedule. Minor changes resulting from the "Dry Run" were made in several of the detailed NDI procedures and accompanying data sheets.

Having incorporated desired changes from the "Dry Run" and after finalizing and reproducing the procedures and all data sheets, final preparations were made for the program to depart for an approximate two-year tour of selected Air Force bases. The four bases visited within each major command were selected by the Air Force Command NDI Monitor representing that command (see Figure 4-1).

Command - Base		TOTAL NDI ACTIVITY* % Ultrasonic	% Eddy Current Surface	% Eddy Current Bolt Hole	% Penetrant	% X-ray
AFLC	Hill	16	24	16	17	27
	Kelly	9	6	10	4	71
	McClellan	18	2	10	50	20
	Tinker	2	7	2	61	28
	Warner Robins	5	6	5	12	72
ATC	Randolph	2	1	1	49	47
	Reese	3	5	2	57	33
	Webb	4	10	7	50	29
	Williams	1	1	2	22	74
MAC	Charleston	16	26	5	52	1
	Dover	9	21	3	48	19
	McChord	26	17	13	25	19
	Travis	16	27	6	45	6
SAC	Carswell	1	15	0	82	2
	Ellsworth	3	6	2	87	2
	Offutt	6	3	0	90	1
	Pease	16	19	0	61	4
TAC	Bergstrom	0	25	16	45	4
	George	4	12	5	58	21
	MacDill	1	10	9	69	11
	Shaw	0	11	4	70	15

*Excluding Magnetic Particle

Data derived from information submitted by NDI technicians - Probably questionable for the Logistic Commands because not all technicians could participate, as was generally the case at the bases.

Figure 4-1. Percent of Regularly Assigned Aircraft Inspections for each NDI Technique at Bases Visited

Randolph Air Force Base

The first base to be visited was an Air Training Command (ATC) base, Randolph Air Force Base, in San Antonio, Texas. The program, now known by its nickname, "Have Cracks-Will Travel," was initiated there on 14 October 1975. The ATC utilizes one standard building design for their NDI shops. One section of the building contains the inspection shops and offices and the other section is an X-ray bay which is large enough to contain an entire fighter aircraft. The facility at Randolph was reasonably new and in excellent condition.

The program utility trailer was unloaded and positioned in one corner of the X-ray bay, since it was utilized in the X-ray part of the program to simulate an aircraft fuselage. The structure samples and all auxiliary equipment were set up in the inspection shop areas which were temperature controlled and well lighted.

The NDI Shop Chief at Randolph was a civilian with a M/Sgt second in command. A total of nine technicians participated in the program at this facility. Four of these were Level 7 and five were Level 5. All were military except one civilian who was retired from the Air Force.

Excluding magnetic particle, inspection methods predominantly used at this facility were penetrant and x-ray. Approximately 49% of the normal inspections conducted were penetrant and about 47% were x-ray. The other 4% was about equally divided between ultrasonic and eddy current (see Figure 4-1). During the four-week period, the nine participants carried out 48-1/2 inspection projects. The program was concluded at Randolph on 19 November 1975.

The weather in San Antonio during the Randolph AFB visit ranged from hot during the first part of the period to mild and cool during the latter part of the period. Although there were great extremes in weather from one base to another during the 2-year period, almost all inspection tasks were conducted inside temperature-controlled buildings, as are most routine Air Force inspections. Therefore, weather should not be considered a variable with relation to the NDI reliability results.

Kelly Air Force Base (Depot)

The second Air Force facility to be visited was also in San Antonio, Texas, the San Antonio Air Logistics Center at Kelly Air Force Base. The move was accomplished on 20 November 1975, and program operations were started on 21 November. Since the depot at Kelly AFB was the monitoring facility for the entire program, management there had been previously briefed and were entirely familiar with the program.

The program structural samples and all auxiliary equipment, including the utility trailer, were initially set up in a large unheated hanger. All samples and equipment, except the trailer, were subsequently moved into an unused office area in the hanger building and a portable heater was set up for use when required. The outside temperature ranged from the low 30's to low 50's during the five weeks at Kelly Air Force Base.

Participating personnel at Kelly AFB were all civilians. All technicians that participated in the eddy current inspection tasks were classified as Aircraft Sheet Metal Mechanics. They were certified to do eddy current and penetrant inspections. The technicians that did ultrasonic inspection tasks were classified as Ultrasonic Equipment Operators, and although they may be certified in other NDI techniques, they primarily do ultrasonic inspections. The technicians that did the penetrant tasks were classified as Aircraft Sheet Metal Inspectors and some of these were also certified in eddy current. All the technicians above, except ultrasonic, do NDI on a part-time basis as required, as part of their regular sheet-metal jobs. The x-ray projects were done by Industrial Radiographers, some of whom were certified in ultrasonics, but they all predominantly do only radiography.

Although airframe NDI functions are normally done in several organizations, radiography accounts for approximately 70% of all the nondestructive inspections done at Kelly (not considering magnetic particle NDI). The other techniques employed range from 3 to 10% each (see Figure 4-1).

Because of the large number of inspectors at Kelly Air Force Base, the maximum size groups useable on the program were scheduled to participate for given periods of time. At the beginning of each scheduled period, the technician briefing was presented and then assignments were made. A total of 47 people participated to carry out 128 inspection tasks.

Inspectors doing the eddy current and penetrant tasks indicated wide variations in their normal frequency of conducting these type inspections. Some do these type inspections frequently and some may have a gap of several months between successive eddy current or penetrant inspections. The radiographers do only radiographic NDI. Some radiographers appear to be used only as helpers and have received a minimum of on-the-job training in the radiography process. The ultrasonic technicians apparently do a considerable amount of ultrasonic inspection for the number of technicians available, and were very busy during the time the program was at Kelly AFB.

Bergstrom Air Force Base

Operations at Kelly AFB were completed just before the Christmas holidays, and all equipment remained there until after the holiday period. All samples and equipment were then packed in the trailer and moved to Bergstrom Air Force Base, Austin, Texas, in early January 1976. Bergstrom AFB is a Tactical Air Command (TAC) base, and like ATC, TAC uses a standard building design for all NDI shops. The shop and office areas of these buildings are similar to the ATC design, but the adjoining x-ray bay is much smaller. The program trailer was a few inches too wide to fit into the x-ray bay. The building was relatively new and in excellent condition.

After setup and briefings at Bergstrom Air Force Base, operations were started on 12 January 1976. All inspectors were military personnel here with a M/Sgt acting as Non Commissioned Officer In Charge (NCOIC). A total of seven technicians participated in the program. Four were Level 7 and three were Level 5 technicians. During the four-week period, a total of 31 inspection tasks were completed. The x-ray projects were performed at a remote location with auxiliary power since this was typical for their facility.

The type of NDI work normally done at Bergstrom AFB included significant efforts in eddy current, penetrant, and x-ray. Considering only the techniques being evaluated, approximately 25% of the routine inspections were eddy current surface probe, 16% were bolt-hole probe, 4% were penetrant and 14% were x-ray. No normal NDI work was done using ultrasonics. Inspection personnel therefore experienced some difficulty with setting up the ultrasonic instrumentation for use on the program samples, but several ultrasonic inspections were accomplished.

The weather at Bergstrom AFB ranged from the low 30's in the mornings into the 70's in the afternoon and was generally sunny and mild.

The program was completed at Bergstrom on 6 February 1976. Program equipment was then transported to Big Spring, Texas for use at the next installation, Webb Air Force Base.

Webb Air Force Base

Webb Air Force Base is an Air Training Command Base and the NDI shop has the same design as the one at Randolph AFB. Again, the trailer was located inside the large x-ray bay.

The program at Webb AFB was started on 17 February 1976, after having set up the equipment and performed the management and technician briefings the prior week. All personnel were military, with a M/Sgt assigned as NCOIC. Ten technicians participated in the program. There were three Level 3, four Level 5, and three Level 7 technicians.

With relation to the NDI techniques of interest to the program, about 50% of the normal inspections that Webb AFB conducted were penetrant and 29% were x-ray inspections. Eddy current NDI ranked third at about 17% for surface probe and bolt hole probe combined. Only about 4% of the inspections at Webb were ultrasonic. No problems were encountered with the use of ultrasonics, however, as was the case at some other locations.

The program was completed at Webb AFB on 12 March 1976, with 36 inspection tasks completed. The weather during the month was cool to warm with high wind most of the time. Dust storms were frequent.

Reese Air Force Base

The program was transported next to Reese Air Force Base in Lubbock, Texas. Reese AFB is also an ATC installation. Equipment was set up and briefings were conducted during the week of 15 March 1976, and the program was started there on 22 March 1976. Since Reese AFB is an ATC base, the hardware was set up in the same configuration as at Randolph AFB and Webb AFB. All personnel were military and the NCOIC was a M/Sgt. Five technicians participated in the program. One was Level 3, three were Level 5, and one was Level 7.

Routine nondestructive inspection techniques normally utilized at Reese included significant efforts in penetrant and x-ray, with considerably smaller efforts in eddy current and ultra-

sonics. Excluding magnetic particle, about 57% of the Reese inspections were penetrant, 33% were x-ray, 7% were eddy current and about 3% were ultrasonic at the time of the program visit. Although instrument setup probably took a little longer than normal, several ultrasonic inspection tasks were completed on the program samples. No problems were encountered with eddy current inspections. A total of 14-1/2 inspection tasks were completed during the period that the program was at Reese AFB.

The program was completed at Reese AFB on 16 April 1976. During the four weeks the weather there was generally mild and windy.

Offutt Air Force Base

The program was next moved to Offutt Air Force Base, Omaha, Nebraska, which is the Headquarters for the Strategic Air Command (SAC). Briefings and equipment setup were completed on 20-21 April 1976 and program operations begun on 22 April.

The NDI shop at Offutt AFB is set up in a portion of a large building. There was adequate room in this area for all NDI equipment, including the x-ray facilities, magnetic particle, penetrant and SOAP (Spectrographic Oil Analysis Program), as well as the ultrasonic and eddy current activities. There was enough room in the area to conveniently set up the reliability program equipment and the structure samples.

All personnel were military and consisted of the NCOIC and 4 technicians. Four personnel were on the standard day shift and one worked a 9 pm to 5 am shift. Two of the five were Level 5 and three were Level 7. During the month they completed 20 inspection tasks.

Inspection techniques of concern to the reliability program that were routinely conducted at Offutt, include penetrant, which was used for about 90% of Offutt 's inspections, eddy current and ultrasonics which together accounted for about 9% of the inspections, and x-ray accounted for less than 1%.

The scheduled visit at Offutt was completed on 17 May 1976. During the four weeks in Omaha, the weather was cool to mild with some rain.

Williams Air Force Base

The next move was to the fourth and last ATC base, Williams AFB in Chandler, Arizona. As at previous ATC bases, the trailer was unloaded and then positioned inside the x-ray bay. All other equipment was set up in the NDI shop area.

The management briefing was given on 27 May 1976 and the trailer was unloaded and the equipment set up the following day. Technician briefings were carried out and program operations were started on 1 June 1976.

All personnel at Williams Air Force Base were military and consisted of the NCOIC and six

technicians on day shift and two technicians on the evening shift. Six technicians participated in the program and completed 19 inspection tasks during the month. All six of the participating technicians were Level 5.

With respect to the inspection techniques being evaluated, on a routine basis Williams AFB used x-ray for about 74% of the inspections normally accomplished and penetrant for about 22% of the inspections. Eddy current, both surface scan and bolt hole scan were utilized for only about 3% of the inspections, but there was little or no requirement for ultrasonic inspection (less than 1%).

The scheduled visit at Williams AFB was completed on 25 June 1976. The weather during the 4 weeks was consistently clear and hot, usually over 100°F during the day.

George Air Force Base

The next move was to the second TAC base visited on the tour, George Air Force Base in Victorville, California. The trailer was moved into the area and unloaded on 1 July 1976, and the management briefing was also given on that day. Setup of equipment was completed the following day and technician briefings and program inspections began on 6 July 1976. Fourteen technicians participated in the program and completed 39 inspection tasks during the visit. Four of the technicians were Level 3, eight were Level 5, and two were Level 7.

NDI routinely utilized at George AFB included all of the four methods evaluated in this program. The penetrant technique was utilized for about 58% of the inspections normally conducted, with x-ray and eddy current next at 21% and 17%, respectively. Ultrasonics is the least used of the techniques and accounted for about only 4% of the total inspections routinely accomplished at George AFB.

The program was completed at George AFB on 30 July 1976. The weather during the month was clear and hot.

Travis Air Force Base

The program was then moved to Travis Air Force Base, which is located in Fairfield, California. This was the first Military Airlift Command (MAC) base to be visited. The NDI facility was in a portion of a larger building. There was adequate room for the work to be done, and lighting and temperature control were standard.

The trailer was moved onto the base on 5 August 1976 and it was unloaded and the equipment set up during 5-6 August. The management briefing was conducted on 6 August, and program operations were started on 9 August 1976. After being unloaded, the trailer was located in a nose hanger at a location suitably remote for operating x-ray equipment.

The NDI shop personnel were a mixture of military and civilian. The shop supervisor was a civilian with a M/Sgt second in command. Thirty-one technicians participated in the pro-

gram and completed 34 inspection tasks. Five of the technicians were Level 7, 18 were Level 5, and eight were Level 3.

At Travis, all NDI techniques of interest to the program were utilized. Penetrant was normally used for about 45% of the inspections, while eddy current accounted for 33%, ultrasonic for 16%, and x-ray for 6%.

The program was completed at Travis on 3 September 1976. The weather during the month was generally mild to cool.

McClellan Air Force Base (Depot)

The program equipment was next transported to the second Air Force Logistics Center, McClellan Air Force Base in Sacramento, California. The NDI shop is located in a large hanger type building partitioned to make several x-ray cells, work areas, and offices. The x-ray cells are lead-lined and, via a large sliding door, open directly onto the concrete apron. The building is located right on the flight line.

On 9 September, the management briefing was given, and on 10 September the trailer was unloaded on the apron in front of the x-ray cells. All structure samples and equipment were moved into one of these cells and the trailer was then moved into an adjacent cell.

On 13 September 1976, the orientation briefing was given to the participating technicians and program operations were started. All personnel were civilian. Twenty-five technicians participated in the program and completed 55-1/2 inspection tasks. Technicians were classified as Nondestructive Inspection Specialist, Ultrasonic Equipment Operator, Industrial Radiographer, and Liquid Penetrant and Magnetic Particle Inspectors. However, within these job classifications, technicians were certified as Level 1 or Level 2 in inspection techniques other than those indicated by the job title.

All NDI techniques were extensively utilized at McClellan AFB. Considering the techniques being evaluated, penetrant accounted for about half of the inspections normally conducted at McClellan AFB, x-ray accounted for approximately 20%, ultrasonics for about 18%, and eddy current for about 12%.

The program was completed at McClellan AFB on 15 October 1976. The weather during the month was mild and sunny.

McChord Air Force Base

The program was moved next to McChord Air Force Base in Tacoma, Washington. This was the second MAC base visited.

The trailer was moved on base on 21 October 1976 and unloaded at the NDI shop. The NDI

shop is on the front portion of a hanger and consists of an office area, a large work area in the mid section and smaller work areas in the rear. The shielded x-ray room is located just outside of the NDI shop in the open hanger. The trailer was moved into the x-ray room for the radiography portion of the program.

The management briefing was given for the Chief of Maintenance and his staff on 22 October 1976. The technician briefing was presented to the participating technicians on 26 October and program operations were started the same day. Technicians were both military and civilian at McChord AFB. The shop supervisor was an Air Force Sargeant.

Six technicians participated in the program and completed 13 inspection tasks. One technician was Level 3 and the other five were Level 5. All NDI techniques of interest to the program were about equally utilized at McChord AFB. Ultrasonic normally accounted for approximately 26% of the inspections conducted there, penetrant for about 25%, eddy current for about 30%, and x-ray for about 19%.

The program was completed at McChord AFB on 19 November 1976. During the month the weather was mild to cool.

Dover Air Force Base

At this point in time, there was an Air Force requirement to determine the inspection reliability at Dover Air Force Base, Dover, Delaware. Dover Air Force Base is a MAC base. Certain "Hot Spot" inspections were scheduled on C-5 aircraft at Dover Air Force Base after the first of the year. It was desired to evaluate Dover inspection reliability prior to performing these "Hot Spot" inspections. Therefore, the program traveled cross-country from Tacoma, Washington, to Dover, Delaware, during the latter part of November, 1976.

The trailer was moved on base and unloaded on 2 December 1976. The management briefing was given to the Chief of Maintenance and his staff, and the technician briefing was given to the day shift and to the swing shift. On 3 December, the grave yard shift was briefed and assignments were made for all shifts.

Personnel at Dover AFB were both military and civilian, and the shop supervisor was an Air Force M/Sgt. Thirty-two technicians participated at Dover AFB and completed 87 inspection tasks. Three technicians were Level 3, seventeen were Level 5, seven were Level 7, and the NCOIC was Level 9 (four technicians did not specify their AFSC).

The NDI shop at Dover AFB consists of one large work area with a partitioned office off to one side. There is one other smaller partitioned work area at the back of the shop. The area is well lighted and temperature controlled. There was no x-ray facility large enough to house the trailer; hence, it was set up in the bay of a hanger and roped off during x-ray operations.

Two additional NDI techniques were added to the program at Dover. One was a semi-automatic ultrasonic device that was designed to rotate around the fastener site (see Section VI for complete description) and the other was the addition of a procedure for use of the

Gulton automatic eddy current bolt hole instrument (see Section VI). Written instructions for the application of both techniques were provided, along with the necessary instruments and practice samples. The ultrasonic device was utilized to inspect sample A and the Gulton instruments were used to inspect samples D, E and F.

All standard NDI techniques are routinely used at Dover AFB; however, the penetrant technique is utilized for almost half of all inspections. Eddy current is used for approximately 24% of the inspections, x-ray for 19%, and ultrasonic for about 9%.

The program was completed at Dover AFB on 21 January 1977. During the month at Dover, the weather varied from fairly warm (40°F) to extremely cold (-4°F) with both rain and snow occurring.

Pease Air Force Base

Since the program was moved to the east coast, the original schedule was modified so that Pease AFB in Portsmouth, New Hampshire would be the next base to be visited. Pease AFB became the second SAC base to participate in the program.

The Chief of Maintenance was briefed in the morning on 28 January 1977 and the participating technicians were briefed in the afternoon. The trailer was brought on base on the same day and all equipment was unloaded and the trailer was parked outside the NDI shop. On the following Monday, 31 January, assignments were made and program operations were started.

The NDI shop at Pease AFB was a part of a larger building and consisted of a large work area with overhead sliding doors at one end. The x-ray room was adjacent in the same end of the building, but was too small to house the trailer. The trailer was parked outside the overhead doors, but was brought inside the NDI shop when the radiography part of the program was initiated. The area was well lighted and temperature controlled.

All NDI personnel at Pease AFB were military. Three technicians participated in the program and completed 12 inspection tasks. All three technicians were Level 5.

Each of the four standard NDI techniques being evaluated are used at Pease AFB, but penetrant inspections constituted about 61% of these normal inspection requirements. Eddy current accounted for about 19%, ultrasonic for about 16%, and x-ray for about 4%.

The program was completed at Pease AFB on 25 February 1977. During the month the weather was relatively mild for Portsmouth in February, but the ground and parking lots were covered with ice and snow the entire time.

Ellsworth Air Force Base

The program was next moved to Ellsworth AFB which is located in Rapid City, South Dakota. Ellsworth AFB was the third SAC base to participate in the program.

The management briefing was held in the morning on 10 March 1977. The trailer was brought on base and unloaded in the afternoon. The equipment was set up and the staff of three were given the technician briefing on the following day. The program was started there on Monday, 14 March 1977.

The NDI shop at Ellsworth AFB, which is located near the flight line, is like those at the TAC bases. The x-ray facility was too small to house the trailer so it was parked outside the building.

All personnel at Ellsworth AFB were military. The three technicians participated in the program and completed 8 inspection tasks. (One week at Ellsworth AFB was nonproductive because the base was closed due to a blizzard.) Two of the technicians were Level 7 and one was Level 5.

Although all of the NDI techniques being evaluated by the program were used at Ellsworth AFB, penetrant was the predominant technique normally employed. Penetrant was utilized for 87% of the inspections carried out at Ellsworth AFB. Eddy current was utilized for about 8% of their inspections and ultrasonic and x-ray accounted for 3 and 2%, respectively.

The program was completed at Ellsworth AFB as scheduled on 8 April 1977. During the month the weather was initially cold with high winds. For the first two weeks the weather improved until it was mild and into the low 70's, however, the winds were high the entire time. On Monday of the third week at Ellsworth AFB, it began to snow in the morning and by Tuesday morning, 10" had fallen and the base was closed. By Wednesday morning 25" had accumulated and the base and town were closed for the remainder of the week. By the middle of the following week temperatures were back up to $60^{\circ}F$.

Hill Air Force Base (Depot)

The next move was to the third AFLC base, Hill Air Force Base in Ogden, Utah. Operations were started there on 20 April 1977. Small equipment and samples were set up in a second story room that was not being used at the time. Entry was from the outside via an outside stairway. The large structure samples were set up in an engine test facility on the ground floor. The x-ray work was done in a separate hanger that was large enough to hold an entire aircraft, so the trailer was moved to that location and used for the program x-ray projects.

All inspection personnel at Hill AFB were civilian with a variety of job titles. Participants were classified as A/C Sheet Metal Mechanics, Machinsts, Weapons Repairman, Ultrasonic Test Equipment Operators, A/C Inspectors, QA Specialists, QA Technicians, and Industrial Radiographers. The A/C Sheet Metal Mechanics were certified for penetrant, or for both eddy current and penetrant. A few were also schooled in ultrasonics but did no ultrasonic work. The Machinsts were generally certified for ultrasonic, eddy current, penetrant, and magnetic particle inspection. The Weapons Repairmen were certified for eddy current only and said that they had conducted no inspections in the last 2 years. The Ultrasonic Test Equipment Operators were certified for ultrasonic and some combination of eddy current, penetrant, and magnetic particle inspections. The one A/C Inspector was certified for

ultrasonic, eddy current, penetrant and magnetic particle inspections. The QA Specialists and Technicians were certified in one or more of the four methods plus radiography. The Industrial Radiographers were certified in radiography only.

Thirty-one technicians participated in the program at Hill AFB and completed 65-1/2 inspection tasks. All standard inspection techniques are utilized at Hill AFB; however, about half of the participating technicians indicated that they do little or no NDI work on a routine basis.

Each of the four methods evaluated were utilized at Hill AFB. Eddy current was normally used for approximately 40% of the inspections carried out. X-ray accounted for about 27% of the inspections, penetrant accounted for 17%, and ultrasonic for 16%.

The program was completed there on 20 May 1977. The weather in Ogden during the month was generally good with a few days of rain and light snow.

Carswell Air Force Base

The program was next moved to Carswell Air Force Base in Ft. Worth, Texas. Carswell was the fourth and last SAC base scheduled for participation.

All equipment and structure samples were set up inside the NDI shop and operations were started there on 30 May 1977. All the inspection personnel were military. Four technicians participated in the program and completed 8 inspection tasks. Two were Level 5 and two were Level 7. Carswell AFB employs each of the four methods evaluated, however, penetrant was utilized for about 82% of the inspections normally conducted. Eddy current was utilized in about 15% of the inspections and x-ray and ultrasonic were used about 2% and 1%, respectively.

The program was completed there on 24 June 1977. The weather during the month was sunny and warm.

Tinker Air Force Base (Depot)

The next move was to the fourth AFLC, Tinker Air Force Base in Oklahoma City, Oklahoma. The program was set up and orientations were given on 30 June and 1 July and program operations were started on 5 July.

The program was conducted in the rear section of a building that houses several labs, shops, and offices. These were normally used for combinations of storage and loading and unloading equipment. It was well lighted and temperature controlled. X-ray work was done on the graveyard shift. The trailer was moved into an open bay in the main aircraft assembly building for the x-ray tasks.

A set of 76 technician proficiency screening samples were added to the program at Tinker. These samples were 16" x 2" x 1/4" with 10 holes each. Inspection techniques to be applied to these specimens were ultrasonic and eddy current bolt hole. These specimens were

to be inspected to investigate the possibility of using a simple structural sample for the screening of inspection personnel.

All inspection personnel at Tinker were civilians with various job titles. Participants were classified as A/C Mechanics, Sheet Metal Workers, A/C Engine Repair Inspectors, A/C Jet Engine Parts Inspectors, Blade Reworkers, and Industrial Radiographers. The A/C Mechanics and Sheet Metal Workers perform ultrasonic, penetrant, or eddy current inspections on a part-time basis and may conduct up to 10 inspections per month. The A/C Engine Repair Inspectors and the A/C Jet Engine Parts Inspectors perform penetrant, eddy current, and ultrasonic inspections on a full-time basis. One inspector may conduct several hundred of these inspections during a typical month but, on the average, over 50% of the inspections are penetrant. The Blade Reworkers conduct penetrant and eddy current inspections on several thousand blades during a typical month. The Industrial Radiographers primarily do radiography, however, they are certified for and do some small amounts of ultrasonic, eddy current and penetrant.

Twenty-six technicians participated in the program and completed 75 inspection projects. Although all standard NDI techniques are utilized at Tinker AFB, penetrant is employed for the largest number of inspections. Excluding the turbine blade inspections (plus magnetic particle), penetrant is utilized for 61% of the inspections, ultrasonic for 2%, eddy current for 9%, and radiographic for 28%. For the turbine blade inspections, penetrant is utilized for about 75% of the inspections and eddy current for about 25%.

The program was completed at Tinker AFB on 12 August 1977. The weather in Oklahoma City during the month was generally sunny and hot.

MacDill Air Force Base

The program was next moved to MacDill AFB in Tampa, Florida. MacDill was the third TAC base visited and the NDI shop is the same as those at the other TAC bases.

The trailer was brought on base on 22 August. It was unloaded on the 23rd of August and the management and technician briefings were also carried out on that day. Program operations were started on the following day.

All inspection personnel were military. Four technicians participated in the program and completed 3-1/2 inspection tasks. Three of the technicians were Level 5 and one was Level 3.

All of the inspection techniques being evaluated were normally utilized at MacDill. Penetrant was used for approximately 69% of the inspections conducted. Eddy current was employed for about 19% of the inspections, x-ray for 11%, and ultrasonic for around 1%.

The program was completed at MacDill AFB on 16 September 1977. The weather in Tampa was generally sunny and warm during the month.

Robins Air Force Base (Depot)

The next move was to Robins Air Force Base, Warner Robins, Georgia, which was the fifth and last Air Logistics Command base visited.

The trailer was moved on base on 21 September 1977. It was unloaded, and the technician briefing given. The management briefing was given during the following day and preparations were made for the program operations to start. The structure samples and equipment were set up in an engine test facility which was being used part-time for x-ray work. Program operations started on 26 September 1977.

The major portion of the NDI technicians at Warner Robins ALC work the midnight to 8:00 am shift because of their heavy x-ray work load. The remaining technicians work on either the day or swing shifts. The majority of program participants were night shift employees and performed their assigned program tasks during the night shift.

All technicians were civilians. Fourteen participated in the program and completed 59 inspection tasks. Of these technicians, twelve were classified as Industrial Radiographers, one as a Radiographer Technician, and one as an NDI Specialist.

All inspection techniques were utilized by the participating technicians, but radiography accounted for over 70% of the inspections normally carried out by them. About 12% of the routine inspections were penetrant inspections, with ultrasonic, eddy current surface probe, and eddy current bolt hole probe accounting for 5 to 6% each.

The program was completed at Warner Robins ALC on 28 October 1977. The weather was generally mild during the visit to this facility.

Charleston Air Force Base

The program was transferred from Warner Robins, Georgia to Charleston, South Carolina. Charleston Air Force Base was the fourth and last MAC base to participate in the program.

The trailer was moved on base on 2 November 1977. It was unloaded that day and the technician briefing was given. The management briefing was scheduled to be given on the following day, but the next morning it was postponed until the following week. Program operations were started on 3 November, however.

All samples and equipment were set up in the NDI shop which was located in a large building with other shops and offices. The NDI shop was a large, long, open room with overhead doors at one end that opened outside onto a concrete drive.

The NDI shop chief was a civilian and the participating technicians were both military and civilian. Six technicians participated in the program and completed 8 inspection tasks. One technician was Level 3, four were Level 5, and one was Level 7. One of the Level 5 technicians had participated in the program at George AFB in July of 1976. During the past

year he transferred to Charleston AFB where he had the opportunity to participate in the program a second time.

Charleston AFB normally utilized all the NDI techniques being evaluated, including the Gulton automatic bolt hole instrument. The major portion of their inspection jobs involved the use of the penetrant technique, which accounted for slightly over 50% of the inspections performed. Eddy current surface probe inspections amounted to approximately 26% of the inspections done, and ultrasonic inspections accounted for about 16% of the inspections. Eddy current bolt hole, eddy current bolt hole automatic and x-ray each ranged from 1 to 3%.

The program was completed at Charleston on 2 December 1977. The weather in Charleston was generally mild during the month and some rain occurred.

Shaw Air Force Base

The trailer was transported to Shaw Air Force Base in Sumter, South Carolina. Shaw AFB was the fourth TAC base to participate in the program, and was the final base on the program schedule.

The trailer was brought on base on 7 December 1977 and unloaded at the NDI shop. The management briefing was presented the following day and the equipment was set up for program operations to begin on 12 December.

The NDI shop had the typical TAC design. All equipment was set up inside the building and the trailer was parked outside.

All participants at Shaw AFB were military. Nine technicians participated in the program and completed 12 inspection tasks. One technician was Level 3, five were Level 5, and three were Level 7.

Shaw AFB has routinely used all NDI techniques under evaluation except ultrasonic, which is seldom required. Penetrant was used for approximately 70% of the inspections normally conducted at Shaw AFB. X-ray was used for approximately 15%, and eddy current surface probe and bolt hole probe for about 15%.

The program was completed at Shaw on 13 January 1978. The weather during the month was cold to mild with some rain occurring.

Summary

From 16 June 1975 to 13 January 1978, the program was taken to 22 Air Force Bases, including the Dry Run at Wright-Patterson (See Figure 4-2). All 5 AFLC's participated, as well as 4 ATC bases, 4 MAC bases, 4 SAC bases, and 4 TAC bases. Excluding Wright-Patterson AFB participants, almost 300 NDI technicians participated in the program and completed approximately 300 separate inspection tasks. This represents the cumulative inspection of over a half-million potential flaw sites (see Figure 4-3).

After completing the work at Shaw, the program trailer with the structure samples was returned to the Lockheed-Georgia Company in Marietta, Georgia to conclude all program tasks. The program had been on the road continuously for 2 years and 3 months. Total distance traveled during that time was 50,000 miles.

BASE	COMMAND	LOCATION	DATA ACQUISITION From	DATA ACQUISITION To
WPAFB	ASD	Dayton, Ohio	06-16-75	06-26-75
Randolph	ATC	San Antonio, Texas	10-14-75	11-19-75
Kelly	AFLC	San Antonio, Texas	11-21-75	12-23-75
Bergstrom	TAC	Austin, Texas	01-12-76	02-06-76
Webb	ATC	Big Spring, Texas	02-17-76	03-12-76
Reese	ATC	Lubbock, Texas	03-22-76	04-16-76
Offutt	SAC	Omaha, Nebraska	04-22-76	05-17-76
Williams	ATC	Chandler, Arizona	06-01-76	06-25-76
George	TAC	Victorville, California	07-06-76	07-30-76
Travis	MAC	Fairfield, California	08-09-76	09-03-76
McClellan	AFLC	Sacramento, California	09-13-76	10-15-76
McChord	MAC	Tocoma, Washington	10-26-76	11-19-76
Dover	MAC	Dover, Delaware	12-03-76	01-21-77
Pease	SAC	Portsmouth, New Hampshire	01-31-77	02-25-77
Ellsworth	SAC	Rapid City, South Dakota	03-14-77	04-08-77
Hill	AFLC	Ogden, Utah	04-20-77	05-20-77
Carswell	SAC	Ft. Worth, Texas	05-30-77	06-24-77
Tinker	AFLC	Oklahoma City, Oklahoma	07-05-77	08-12-77
MacDill	TAC	Tampa, Florida	08-24-77	09-16-77
Robins	AFLC	Warner Robins, Georgia	09-26-77	10-28-77
Charleston	MAC	Charleston, South Carolina	11-03-77	12-02-77
Shaw	TAC	Sumter, South Carolina	12-12-77	01-13-78

Figure 4-2. Field Data Acquisition Schedule

o A, B, C, D, E, F, G = Structure Sample Designations
o UT = Ultrasonic
o RT = Radiography
o Auto - Automatic
o PT = Penetrant
o FT = Eddy Current Surface Scan
o BH = Bolt Hole

COMMAND	BASE	NO. TECHNICIANS PARTICIPATING	A^{UT}	A^{UT}_{Auto}	A^{ET}	B^{ET}	$B^{ET}_{Overhead}$	B^{RT}	C^{UT}	C^{PT}	D^{UT}	D^{ET}_{BH}	$D^{ET}_{BH\ Auto}$	E^{ET}_{BH}	$E^{ET}_{BH\ Auto}$	F^{UT}	F^{ET}_{BH}	$F^{ET}_{BH\ Auto}$	G^{UT}	C^{ET}	TOTAL NO. SAMPLES INSPECTED
AFLC	Hill	21	4	-	4	5	-	4	1	8	5	3	2	9.50	4.50	4	5	1.50	-	-	65.50
	Kelly	47	3	-	15	20	4	8	[illegible]	9	3	20	-	20	-	3	20	-	-	-	128
	McClellan	25	5	-	3	3	-	5	3	10	3	4	2	5	2.50	3	4	3	-	-	55.50
	Tinker	26	6	1	6	7	-	3	3	5	3	7	1	12	3	3	7	2	3	3	75
	W. R. Robins	24	3	-	3	5	-	3	-	3	-	1	-	10	4	-	10	3	3	11	59
	AFLC Totals	143	21	2	31	40	4	23	10	35	14	35	5	56.50	14	13	46	9.50	6	14	383
ATC	Randolph	9	5	-	5	4	3	3	4	3.50	6	3	-	5	-	4	3	-	-	-	48.50
	Reese	5	1	-	2	3	-	2	-	1.50	1	2	-	1	-	-	1	-	-	-	14.50
	Webb	10	2	-	3	4	.50	5	2	4	3	3.50	-	4	-	2	3	-	-	-	36
	Williams	6	-	-	3	3	-	3	-	3	-	3	-	2	-	-	2	-	-	-	19
	ATC Totals	30	8	-	13	14	3.50	13	6	12	10	11.50	-	12	-	6	9	-	-	-	118
MAC	Charleston	6	2	-	-	1	-	-	-	-	-	-	-	2	1	-	-	-	2	-	8
	Dover	32	6	2	5.50	10	-	9	7	1	10.50	7	2	12	2	4	7	2	-	-	87
	McGuire	7	1	-	2	1.50	-	1	1	-	1	1	-	2.50	-	1	1	-	-	-	13
	Travis	31	3	-	-	5	-	12	2	1	4	2	-	2	-	2	1	-	-	-	34
	MAC Totals	76	12	2	7.50	17.50	-	22	10	2	15.50	10	2	18.50	3	7	9	2	2	-	142
SAC	Carswell	4	1	-	1	1	-	-	-	-	-	1	-	1	-	-	1	-	-	-	8
	Ellsworth	3	2	-	-	1	-	-	1	-	-	1	1	1	1	-	1	-	-	-	8
	Offutt	5	-	-	3	3	1	-	-	4	1	3	-	3	-	-	2	-	-	-	20
	Pease	3	-	-	-	2	-	1	-	1	.50	1	1	1	1.50	-	1	1	-	-	12
	SAC Totals	15	3	-	4	7	1	1	1	5	1.50	5	2	6	2.50	-	5	1	-	-	48
TAC	Bergstrom	7	2	-	3	4.50	1.50	2	2	4	2	2	-	3	-	3	2.25	-	-	-	31.25
	George	14	5	-	4	6.50	-	-	3	4	3.50	3	-	5	-	-	5	-	-	-	39
	MacDill	4	-	-	-	-	-	-	-	-	-	-	-	1.50	-	-	-	-	-	2	3.50
	Shaw	9	-	-	1	2.50	-	-	-	1	-	-	-	3	1	-	.50	1	1.25	-	12.25
	TAC Totals	34	8	-	8	13.50	1.50	2	5	9	5.50	5	-	12.50	1	3	7.75	1	1.25	2	86
TOTALS	Field	155	32	2	32.50	52	6	38	22	28	32.50	32.50	4	49	7.50	16	30.75	4	3.25	2	394
	Field & Depot	298	53	4	63.50	92	10	61	32	63	46.50	71.50	9	105.50	21.50	29	76.75	13.50	9.75	16	777*

Depot

Field

*Represents the inspection of 541,301 potential flaw sites

Figure 4-3. Inspection Tasks Completed at each Base

SECTION V. DATA COLLECTED

The nucleus of all the NDI reliability data acquired in this program is composed of flaw "find" or "no find" information for each cataloged flaw site inspected by each participant. Flaw sites cataloged at the start of the data acquisition phase were those identified as suspect fatigue cracks of lengths estimated initially by nondestructive methods. Subsequent structure teardown and detailed examination at the conclusion of the data acquisition phase provided more accurate data on the flaw content. Schedules of cataloged flaws which were identified at the beginning of the data acquisition effort are listed along with participant identification numbers for each structure sample/NDI method combination in Figures 5-1 through 5-16 in matrix formats. Entries are coded with a numeral one (1) denoting a find, a zero (0) denoting a no-find, and a dash (-) indicating that the individual did not examine that particular flaw site.

Data summaries are provided at the bottom of each column and at the end of each row. Column summaries provide the total number of false calls (F) by each technician, the ratio of finds-to-total flaw count (Σ/N) and that ratio in percent (%). Row summaries are given on the final page of each figure in terms of total finds ratioed to total number of technicians (Σ/n) and that ratio in percent (%). Cataloged suspect flaw locations which were not subsequently confirmed as containing cracks after teardown are coded with an asterisk (*). The post-teardown flaw information which is corrected for size error is provided in Section VII, "Teardown Evaluation" and is employed in the final data analysis contained in Sections X and XI. The flaw identification (ID) numbers which are listed on the above figures are the ones used in the data acquisition phase of the program. The same flaws are listed with crack identification numbers in Section VII, using prefix and suffix modifications to the basic identification numbers listed in this section. For example, flaw number 77a in Figure 5-1 is identified as crack number A277A in Figure 7-5. This change was incorporated to facilitate computerized data storage and retrieval.

A large quantity of additional raw data, in both numerical and narrative form, was collected but the volume exceeds the limits of convenient presentation in this report. The categories for the additional data are as follows:

- Facility Evaluation
- Daily Log
- Equipment Performance
- Technician Profile
- Inspection Log (equipment settings)

The detailed content within each category is presented in Figures 8-1 through 8-7 in Section VIII, Data Storage and Retrieval and as it was originally formatted on raw data sheets in Figures 5-17 through 5-29.

Flaw ID	Flaw Size	Technician ID																
		0201	0202	0204	C207	C208		C3E1	C3E2	C3E3	C3E4	C3E5	C3E7	C3E9	03E10	C3E11	C3E13	C3E15
77a	0.09	0	0	1	0	0		0	0	0	1	0	0	0	0	0	0	0
122	0.09	1	0	0	0	0		0	0	1	1	0	0	0	0	0	0	1
132	0.10	1	0	0	0	0		0	0	0	0	0	0	1	0	0	0	0
121	0.10	1	0	1	0	0		1	0	1	1	0	0	0	1	0	0	0
75	0.10	1	0	1	0	0		0	0	0	0	0	1	0	0	0	0	0
76b	0.12	1	0	1	0	0		0	0	0	1	1	1	1	0	0	0	0
80	0.12	1	1	1	0	0		0	0	0	1	0	0	0	0	0	0	0
77b	0.13	1	1	1	0	0		0	0	0	1	1	1	0	1	1	1	1
79d	0.13	1	0	0	0	0		0	0	0	0	0	0	1	0	0	0	1
125	0.13	1	0	0	1	0		0	0	1	0	0	0	0	1	1	0	0
133	0.14	0	0	0	0	0		0	-	0	0	0	0	0	0	0	0	0
12a	0.15	1	1	1	1	0		0	0	1	1	0	0	0	0	0	1	1
78	0.16	1	1	1	0	0		0	0	0	1	0	1	0	0	0	1	1
9b	0.16	1	1	1	1	0		0	0	1	0	1	0	1	1	1	1	0
131	0.16	1	1	1	0	0		0	0	1	1	0	1	0	0	0	1	1
7	0.16	1	0	1	1	0		0	-	1	1	0	0	0	0	0	0	1
8a	0.17	0	0	1	0	0		0	-	1	0	0	0	0	0	0	0	0
130	0.19	1	1	1	1	0		0	1	1	1	1	0	0	1	1	1	1
10d	0.19	1	1	1	1	0		1	1	0	0	1	1	0	1	1	1	0
101	0.20	0	0	1	1	1		0	-	0	0	0	0	0	1	0	0	1
76a	0.21	1	0	1	0	1		0	1	0	1	1	0	0	1	1	0	1
81b	0.21	1	1	1	1	1		0	1	1	1	0	0	1	1	1	0	1
123	0.21	1	1	1	1	1		0	1	0	1	0	1	0	0	1	1	1
8c	0.21	1	0	1	0	0		0	0	1	0	1	1	0	1	1	1	0
9a	0.22	1	1	1	1	1		0	1	1	1	1	0	1	1	1	0	1
11b	0.22	1	1	1	1	0		0	1	1	1	1	0	1	1	1	1	1
79a	0.23	1	1	1	1	1		0	1	0	1	1	1	0	1	1	1	1
12b	0.23	1	1	1	1	1		0	1	1	1	1	0	1	1	1	1	1
8b	0.23	1	0	1	0	0		0	-	1	0	1	0	0	1	1	1	0
10a	0.24	1	1	1	1	0		0	1	1	0	1	0	1	1	1	0	0
81a	0.25	1	1	1	1	1		0	1	1	1	1	1	1	1	1	0	1
11a	0.29	1	1	1	1	0		1	1	1	1	1	0	1	1	1	1	1
10b	0.31	1	1	1	1	0		1	1	1	0	1	0	1	1	1	0	0
124	0.33	1	1	1	1	1		0	1	1	1	0	0	0	1	0	1	1
20	0.34	0	1	1	1	0		0	0	1	0	0	0	0	1	1	1	0
4b	0.39	1	1	1	1	1		1	-	1	1	1	1	1	1	1	1	1
6a	0.46	1	0	1	1	1		1	-	1	1	1	0	1	1	1	1	1
4a	0.52	1	1	1	1	1		1	-	1	1	1	1	1	1	1	1	1
5a	0.52	1	1	1	1	1		1	-	0	0	0	1	1	1	1	1	1
6b	0.57	1	0	1	1	1		1	-	1	1	1	0	1	1	1	1	1
5b	0.66	1	1	1	1	1		1	-	0	1	1	1	1	1	1	1	1
4c	1.05	1	1	1	1	1		1	-	1	1	1	1	1	1	1	1	1
31	1.92	1	1	0	0	1		0	0	0	0	0	0	0	1	0	0	0
F		3	2	10	1			28	35	7	4	0	36	5	6	1	54	3
Σ/N		38/43	[illegible]	37/43	26/43	17/43		11/43	14/21	26/43	27/43	22/43	15/43	19/43	29/43	26/43	23/43	26/43
%		88.4	[illegible]	86.0	60.5	39.5		25.6	[illegible]	60.5	62.8	51.2	34.9	44.2	67.4	60.5	53.5	60.5

FIGURE 5-1. RAW DATA SHEET - SAMPLE A, EDDY CURRENT SURFACE SCANS

Flaw ID	Flaw Size	Technician ID																
		03E16	03E17	03E18	03E20		0401	0402	0403		0501	0505	0509		0605	0606		
77a	0.09	0	0	0	0		0	0	1		1	1	0		0	0		
122	0.09	0	1	0	0		1	0	0		1	0	1		0	0		
132	0.10	0	0	0	0		0	0	0		0	1	1		0	0		
121	0.10	0	0	1	0		1	0	0		1	0	0		0	0		
75	0.10	0	0	1	0		1	0	1		1	1	1		0	1		
76b	0.12	1	0	1	0		1	0	1		1	1	1		1	1		
80	0.12	0	0	1	0		1	0	1		1	1	1		0	0		
77b	0.13	1	0	1	0		1	0	1		1	1	1		1	0		
79d	0.13	0	0	1	0		1	0	1		1	1	1		0	0		
125	0.13	1	0	1	0		1	0	0		1	0	1		1	0		
133	0.14	0	0	0	0		1	0	0		0	1	1		0	1		
12a	0.15	1	0	1	1		1	0	0		1	0	1		1	0		
78	0.16	1	0	1	0		1	1	1		1	1	0		0	0		
9b	0.16	0	0	1	0		1	0	0		1	1	0		1	1		
131	0.16	1	0	1	0		1	1	0		0	1	1		1	1		
7	0.16	0	0	0	0		[illegible]	1	0		0	0	0		0	1		
8a	0.17	0	1	1	0		1	0	0		0	1	1		0	0		
130	0.19	1	0	1	1		1	0	0		1	1	1		1	1		
10d	0.19	1	0	1	1		1	0	0		1	0	0		1	1		
101	0.20	1	1	1	0		1	1	0		0	0	0		0	1		
76a	0.21	0	0	1	0		1	1	1		1	0	1		1	1		
81b	0.21	1	1	1	0		1	0	0		1	0	1		1	1		
123	0.21	1	0	1	1		1	1	1		1	0	1		0	0		
8c	0.21	0	1	1	0		1	1	0		0	1	1		0	1		
9a	0.22	1	1	1	0		1	0	1		1	1	1		1	1		
11b	0.22	0	0	1	1		1	0	0		1	0	1		1	1		
79a	0.23	1	0	1	0		1	1	1		1	0	1		1	0		
12b	0.23	1	0	0	1		1	1	0		1	0	1		1	0		
8b	0.23	0	0	1	1		1	1	1		0	1	1		0	1		
10a	0.24	1	0	1	1		1	0	0		1	1	1		1	1		
81a	0.25	1	1	1	0		1	1	1		1	0	1		1	1		
11a	0.29	0	1	1	1		1	0	0		1	0	1		1	1		
10b	0.31	1	1	1	1		1	0	0		1	1	0		1	1		
124	0.33	1	0	1	1		1	1	1		1	1	1		1	0		
20	0.34	0	0	1	1		0	0	1		1	0	1		0	1		
4b	0.39	1	1	1	1		1	1	1		1	1	1		0	1		
6a	0.46	1	1	1	1		1	1	1		1	1	1		0	1		
4a	0.52	1	1	1	1		1	1	1		1	1	1		0	1		
5a	0.52	1	0	1	1		1	1	1		1	1	1		0	1		
6b	0.57	1	1	1	1		1	1	0		1	1	1		0	1		
5b	0.66	1	0	1	1		1	1	1		1	1	1		0	1		
4c	1.05	1	1	1	1		1	1	1		1	1	1		0	1		
31	1.92	0	0	0	0		0	0	0		0	0	0		0	0		
F		3	91	46	5		147	13	2		2	23	38		18	12		
Σ/N		25/43	14/43	36/43	19/43		38/43	19/43	21/43		34/43	26/43	34/43		19/43	27/43		
%		58.1	32.6	83.7	44.2		88.4	44.2	48.8		79.1	60.5	79.1		44.2	62.8		

FIGURE 5-1. RAW DATA SHEET - SAMPLE A, EDDY CURRENT SURFACE SCANS (Continued)

Flaw ID	Flaw Size	Technician ID 0701	0702	0703	0801	0803	0806	0901	0903	0909	09011	1113	1118	1121
77a	0.09	0	0	0	0	0	0	0	0	1	0	1	1	0
122	0.09	0	0	0	0	0	0	1	0	0	0	1	1	0
132	0.10	0	0	0	1	0	0	0	0	0	0	1	0	0
121	0.10	0	0	0	1	0	0	1	0	0	0	1	1	0
75	0.10	0	0	0	1	0	0	0	0	0	0	1	1	1
76b	0.12	1	1	0	0	0	0	0	0	0	1	1	0	1
80	0.12	0	0	0	0	0	0	0	0	1	1	1	1	1
77b	0.13	0	1	0	1	0	0	0	0	0	0	1	1	1
79d	0.13	0	0	0	0	0	0	0	0	0	1	1	1	0
125	0.13	0	0	0	1	0	0	0	0	0	0	1	0	0
133	0.14	0	1	0	0	0	1	1	0	1	1	1	0	0
12a	0.15	0	0	0	0	0	0	0	0	1	0	1	1	1
78	0.16	0	1	0	0	0	0	0	0	1	0	1	1	1
9b	0.16	1	1	0	1	0	0	0	0	0	0	1	1	1
131	0.16	0	0	1	1	0	0	0	0	0	0	1	1	1
7	0.16	0	0	0	1	0	0	0	0	0	1	1	1	0
8a	0.17	0	0	0	0	0	0	0	0	0	0	1	0	1
130	0.19	1	1	0	1	0	1	0	0	1	1	1	0	1
10d	0.19	0	1	1	1	0	0	0	0	1	1	1	1	1
101	0.20	0	0	0	1	0	0	0	0	1	0	0	0	1
76a	0.21	1	1	0	1	1	1	0	0	1	1	1	1	1
81b	0.21	0	1	0	1	1	1	0	0	0	1	0	1	1
123	0.21	0	0	1	1	0	1	0	0	1	1	1	1	1
8c	0.21	1	1	1	0	0	0	0	0	0	0	1	0	1
9a	0.22	0	1	0	0	1	0	0	0	1	1	1	0	1
11b	0.22	1	1	0	1	0	0	0	0	1	1	1	1	1
79a	0.23	0	1	0	1	1	1	0	0	1	1	1	1	1
12b	0.23	1	1	1	1	1	1	1	0	0	0	0	1	1
8b	0.23	1	1	0	1	0	0	0	0	0	0	1	0	1
10a	0.24	0	0	1	1	0	0	0	0	1	0	1	1	1
81a	0.25	1	1	0	0	1	1	0	0	1	0	1	1	0
11a	0.29	0	0	1	0	0	1	0	0	1	0	1	1	1
10b	0.31	0	1	1	0	0	0	0	0	1	1	1	1	1
124	0.33	0	0	0	1	0	1	0	0	0	1	0	1	1
20	0.34	0	0	0	1	0	1	0	1	1	0	1	0	1
4b	0.39	1	1	1	1	1	1	1	1	1	1	1	1	1
6a	0.46	0	1	0	1	1	1	0	0	1	1	1	1	1
4a	0.52	1	1	1	1	1	1	1	1	1	1	1	1	1
5a	0.52	0	1	0	1	1	1	0	0	1	1	1	1	1
6b	0.57	1	1	0	1	1	1	0	0	1	1	1	1	1
5b	0.66	0	1	0	1	1	1	0	0	1	1	1	1	1
4c	1.05	1	1	1	1	1	1	1	1	1	1	1	1	1
31	1.92	0	0	0	0	0	0	1	0	0	0	0	0	0
F		22	4	3	6	5	4	4	1	3	99	8	38	16
Σ/N		13/43	24/43	11/43	28/43	13/43	18/43	8/43	4/43	25/43	22/43	38/43	31/43	33/43
%		30.2	55.	25.6	65.1	30.2	41.9	18.6	9.3	58.1	51.2	88.2	72.1	76.7

FIGURE 5-1. RAW DATA SHEET - SAMPLE A, EDDY CURRENT SURFACE SCANS (Continued)

Flaw ID	Flaw Size	Technician ID 1208	1310	1313	1316	1326	1331	16E5	16E7	16E9	16E10	1704	1807	1810
77a	0.09	1	0	0	0	0	0	0	1	0	0	0	0	0
122	0.09	0	0	0	0	0	1	0	1	1	-	0	0	0
132	0.10	0	0	0	0	0	1	0	1	0	0	0	0	0
121	0.10	0	0	0	1	0	1	1	1	0	-	1	0	0
75	0.10	0	0	0	0	0	1	0	1	0	1	0	0	0
76b	0.12	0	0	0	0	0	1	1	1	0	1	1	0	0
80	0.12	1	0	0	1	0	1	1	1	1	1	0	0	0
77b	0.13	1	0	0	0	0	1	0	1	1	1	1	0	0
79d	0.13	1	0	0	0	0	1	0	1	1	1	0	0	0
125	0.13	1	0	0	0	0	0	1	1	0	1	1	0	0
133	0.14	0	0	0	0	0	0	0	1	1	0	0	1	0
12a	0.15	0	0	0	0	0	1	0	1	1	-	0	0	0
78	0.16	1	0	0	0	0	1	0	1	1	0	0	0	0
9b	0.16	0	0	0	0	0	1	0	1	1	1	1	0	[illegible]
131	0.16	0	0	0	0	0	1	1	1	1	1	0	0	0
7	0.16	0	0	0	0	0	0	0	0	1	0	0	0	0
8a	0.17	0	1	0	0	0	0	0	0	1	0	0	0	0
130	0.19	1	0	0	1	0	0	0	0	1	1	1	0	[illegible]
10d	0.19	1	1	1	1	0	1	1	1	1	-	0	0	0
101	0.20	0	0	0	1	0	1	1	1	1	1	0	0	0
76a	0.21	1	0	0	1	0	1	1	1	1	1	0	0	0
81b	0.21	1	0	0	0	0	1	1	1	1	1	1	0	0
123	0.21	1	0	0	0	0	1	1	0	0	1	1	0	0
8c	0.21	1	1	0	1	0	1	1	0	0	1	0	0	0
9a	0.22	0	0	0	1	0	1	1	1	1	1	1	0	0
11b	0.22	1	1	1	1	0	1	1	1	1	-	1	0	0
79a	0.23	1	0	0	1	0	1	0	1	1	1	1	0	0
12b	0.23	1	1	0	1	0	1	1	1	1	-	1	0	0
8b	0.23	0	1	0	1	0	1	1	0	0	1	0	0	0
10a	0.24	1	1	1	1	0	1	1	1	1	-	1	0	0
81a	0.25	0	1	0	1	0	1	1	1	1	1	1	0	0
11a	0.29	1	1	1	1	1	1	1	1	1	-	1	0	1
10b	0.31	1	1	1	1	0	1	0	1	1	-	0	0	0
124	0.33	0	1	0	0	0	1	1	1	1	1	1	0	0
20	0.34	0	1	0	0	0	1	1	1	0	1	1	0	0
4b	0.39	1	1	1	1	0	1	1	1	1	1	1	0	1
6a	0.46	1	0	1	1	0	1	1	1	1	0	1	0	0
4a	0.52	1	1	1	1	0	1	1	1	1	1	1	0	1
5a	0.52	1	1	1	1	1	1	1	0	1	1	0	0	0
6b	0.57	1	0	1	1	0	1	1	1	1	0	1	0	0
5b	0.66	1	1	1	1	0	1	1	0	1	1	0	0	0
4c	1.05	1	1	1	1	0	1	1	1	1	1	1	0	1
31	1.92	0	-	-	-	-	-	-	-	-	-	-	-	-
F		5	15	2	40	0	7	3	13	5	2	0	79	0
Σ/N		25/43	17/42	12/42	23/42	2/42	[illegible]	27/42	34/42	32/42	25/33	22/42	1/42	6/42
%		58.1	40.5	28.6	54.8	4.8	16.7	64.3	81.0	76.2	75.8	52.4	2.4	14.3

FIGURE 5-1. RAW DATA SHEET - SAMPLE A, EDDY CURRENT SURFACE SCANS (Continued)

Flaw ID	Flaw Size	Technician ID														Σ/n	%
		1811	1813	1819	1820		2008	2011	2013		2202						
77a	0.09	0	0	0	0		0	0	1		0					11/62	17.7
122	0.09	0	1	0	0		1	0	–		0					16/57	28.1
132	0.10	1	0	0	0		1	0	0		0					10/62	16.1
121	0.10	0	1	1	0		0	0	–		0					20/60	33.3
75	0.10	0	0	1	0		0	0	0		0					18/62	29.0
76b	0.12	1	0	1	0		0	0	0		0					27/62	43.5
80	0.12	0	0	0	0		0	0	1		0					23/62	37.1
77b	0.13	0	0	1	0		0	0	0		0					30/62	48.4
79d	0.13	0	0	0	0		0	0	1		0					18/62	29.0
125	0.13	0	1	1	0		1	0	0		1					22/62	35.5
133	0.14	0	–	1	0		0	0	1		1					16/60	26.7
12a	0.15	0	0	0	1		1	0	–		0					24/60	40.0
78	0.16	1	0	1	0		0	0	1		1					27/62	43.5
9b	0.16	1	0	1	0		1	0	0		1					32/62	51.6
131	0.16	0	0	1	0		1	0	0		0					29/62	46.8
7	0.16	0	–	1	1		0	0	1		0					17/60	28.3
8a	0.17	0	–	0	0		0	0	0		0					10/60	16.7
130	0.19	1	1	1	0		1	0	0		1					41/62	66.1
10d	0.19	0	1	1	1		1	0	–		0					38/60	63.3
101	0.20	0	–	0	0		1	0	1		1					23/60	38.3
76a	0.21	0	0	1	0		0	0	0		1					36/61	59.0
81b	0.21	1	0	1	0		0	0	0		1					37/62	59.7
123	0.21	1	0	1	0		1	0	1		1					37/62	59.7
8c	0.21	0	–	1	0		0	1	0		1					29/61	47.5
9a	0.22	1	0	1	0		0	0	1		1					40/59	67.8
11b	0.22	1	0	1	1		1	0	–		0					41/60	68.3
79a	0.23	0	0	1	0		0	0	1		1					40/62	64.5
12b	0.23	0	1	0	1		0	0	–		1					41/60	68.3
8b	0.23	0	–	1	0		0	1	0		1					28/60	46.7
10a	0.24	0	1	1	1		1	0	–		0					38/60	63.3
81a	0.25	1	0	1	0		1	0	1		1					44/61	72.1
11a	0.29	1	1	1	1		0	1	–		1					46/60	76.7
10b	0.31	0	0	1	1		0	0	–		1					37/60	61.7
124	0.33	0	1	1	0		1	0	1		1					38/62	61.3
20	0.34	1	0	0	1		1	0	1		1					30/62	48.4
4b	0.39	0	–	1	1		1	1	1		1					56/60	93.3
6a	0.46	0	–	0	1		1	1	1		1					46/60	76.7
4a	0.52	0	–	1	1		1	1	1		1					56/60	93.3
5a	0.52	1	–	0	1		1	0	1		1					45/60	78.3
6b	0.57	0	–	1	1		1	1	1		1					47/60	78.3
5b	0.66	1	–	1	1		1	0	1		1					47/60	[illegible]
4c	1.05	0	–	1	1		1	1	1		1					56/60	93.3
31	1.92	–	–	–	–		–	–	–								
F		8	36	24	1		88	2	52		6						
Σ/N		14/42	[illegible]/29	30/42	16/42		22/42	8/42	20/33		26/42						
%		33.3	[illegible]	71.4	38.1		52.4	19.0	60.6		61.9						

FIGURE 5-1. RAW DATA SHEET - SAMPLE A, EDDY CURRENT SURFACE SCANS (Continued)

Flaw ID	Flaw Size	C202	C204	C206	C208	C209	C341	C342	C343	C402	C407	C501	C502	C606
77a	0.09	0	0	0	0	0	0	0	0	0	1	0	0	0
122	0.09	0	0	0	0	0	0	0	0	0	1	0	0	0
132	0.10	0	0	0	0	0	1	0	0	0	0	0	0	0
121	0.10	0	0	0	0	0	1	0	0	0	0	0	0	0
75	0.10	0	0	0	0	0	0	0	0	1	1	0	0	1
76b	0.12	0	0	0	0	0	1	0	0	0	1	0	0	1
80	0.12	0	0	0	0	0	1	0	0	0	1	0	0	0
77b	0.13	0	0	0	0	0	0	0	0	0	1	0	1	0
79d	0.13	0	0	0	0	0	1	0	0	0	1	0	0	0
125	0.13	0	0	0	0	0	0	0	0	0	1	0	0	0
133	0.14	0	0	0	0	0	1	0	0	0	0	0	0	0
12a	0.15	0	0	0	0	0	0	0	0	0	0	0	0	1
78	0.16	0	1	0	0	0	1	0	0	0	1	0	0	1
9b	0.16	0	1	0	0	0	1	0	0	0	0	0	1	1
131	0.16	0	1	0	0	0	1	0	0	0	1	0	0	1
7	0.16	0	0	0	0	0	0	0	0	0	0	0	0	0
8a	0.17	0	0	0	0	0	0	0	0	0	0	0	0	0
130	0.19	0	1	0	0	0	0	0	0	0	1	0	0	1
10d	0.19	0	1	0	0	0	1	0	0	0	0	0	0	0
101	0.20	0	0	0	0	0	0	0	0	0	0	0	0	0
76a	0.21	0	0	0	0	0	1	0	0	1	1	0	1	1
81b	0.21	0	1	1	0	1	0	0	0	0	1	0	0	1
123	0.21	0	1	1	0	1	1	0	0	0	1	0	1	1
8c	0.21	0	1	1	0	0	0	0	0	0	1	0	0	0
9a	0.22	0	1	1	0	0	1	0	0	0	1	0	0	1
11b	0.22	0	1	1	0	1	0	0	0	0	0	0	0	1
79a	0.23	0	1	0	0	0	1	0	0	0	0	0	0	1
12b	0.23	0	0	0	0	1	1	0	0	0	1	0	0	1
8b	0.23	0	1	0	0	0	0	0	0	0	1	0	0	0
10a	0.24	0	1	0	0	1	1	0	0	0	1	0	0	1
81a	0.25	0	1	0	0	1	1	0	0	0	0	0	0	1
11a	0.29	0	1	0	0	1	0	0	0	0	1	0	1	1
10b	0.31	0	1	0	0	0	1	0	0	0	1	0	0	1
124	0.33	0	1	1	0	1	0	0	1	0	1	0	1	1
20	0.34	0	0	0	0	0	0	0	1	0	1	0	0	1
4b	0.39	0	1	1	1	1	1	1	1	1	1	0	1	1
6a	0.46	0	1	1	1	1	1	1	1	1	1	1	1	1
4a	0.52	0	1	1	0	1	1	1	1	1	1	0	1	1
5a	0.52	0	1	1	1	0	1	1	1	1	0	0	1	1
6b	0.57	0	1	1	0	1	1	1	1	1	1	1	1	1
5b	0.66	0	1	1	1	0	1	1	1	1	0	0	1	1
4c	1.05	0	1	1	0	1	1	1	1	1	1	0	1	1
31	1.92	0	1	0	1	1	1	0	1	0	1	0	0	0
F		0	2	2	0	0	99	11	5	5	8	1	2	14
Σ/N		0/43	25/43	13/43	5/43	14/43	26/43	7/43	10/43	9/43	29/43	2/43	13/43	27/43
%		0	[illegible]	30.2	11.6	32.6	60.5	16.3	23.3	20.9	67.4	4.7	30.2	62.8

FIGURE 5-2. RAW DATA SHEET - SAMPLE A, ULTRASONIC SHEAR WAVE SCANS (Continued)

Flaw ID	Flaw Size	Technician ID 0901	0906	0909	0910	0912		1010	1015	1017	1022		1102	1107	1113	1115	1118	
77a	0.09	0	0	0	0	1		1	0	1	0		1	1	-	1	0	
122	0.09	0	0	0	0	0		0	0	1	0		1	1	1	1	0	
132	0.10	0	0	0	0	1		0	0	0	0		1	1	-	1	0	
121	0.10	0	0	1	0	0		0	0	0	0		0	0	0	0	0	
75	0.10	0	0	0	0	1		1	0	0	0		1	1	-	1	0	
76b	0.12	0	0	0	0	1		1	0	1	0		1	1	-	1	0	
80	0.12	0	0	0	0	0		0	0	0	0		1	1	-	1	0	
77b	0.13	0	0	1	0	1		1	0	1	0		1	1	-	1	1	
79d	0.13	0	0	0	0	0		0	0	0	0		1	1	-	1	0	
125	0.13	0	0	0	0	1		0	0	0	0		1	1	-	1	0	
133	0.14	0	0	0	0	1		0	0	0	0		0	1	0	0	0	
12a	0.15	0	0	0	0	0		0	0	0	0		0	1	0	0	0	
78	0.16	0	0	0	0	1		0	0	1	0		1	1	-	1	1	
9b	0.16	0	0	0	0	0		1	0	0	0		1	1	-	1	0	
131	0.16	0	0	0	0	0		0	0	0	0		1	1	-	0	1	
7	0.16	0	0	0	0	0		0	0	0	0		0	0	0	0	1	
8a	0.17	0	0	0	0	0		0	0	0	0		1	1	1	1	0	
130	0.19	0	0	1	0	0		1	1	1	0		1	0	-	1	1	
10d	0.19	0	0	0	0	0		1	0	1	0		0	0	0	0	0	
101	0.20	0	0	0	0	1		0	0	0	0		0	0	0	0	0	
76a	0.21	0	0	0	0	1		1	0	1	0		1	1	-	1	0	
81b	0.21	1	0	1	0	1		1	0	0	0		1	1	-	1	1	
123	0.21	0	0	0	0	1		0	0	1	0		1	1	-	1	0	
8c	0.21	0	0	0	0	0		0	0	0	0		0	1	1	1	0	
9a	0.22	1	0	0	0	1		1	0	1	0		1	1	-	1	1	
11b	0.22	0	0	0	0	0		1	0	1	0		1	1	1	0	1	
79a	0.23	0	0	0	0	0		0	0	1	0		1	1	-	1	0	
12b	0.23	0	0	0	0	1		0	0	1	0		1	0	1	1	1	
8b	0.23	0	0	0	0	0		0	0	0	0		0	1	0	1	1	
10a	0.24	0	0	0	1	1		1	0	1	0		1	1	1	1	0	
81a	0.25	0	0	0	0	0		1	0	0	0		1	1	-	0	1	
11a	0.29	0	0	0	0	0		1	0	1	0		1	1	1	1	1	
10b	0.31	0	0	0	1	0		1	0	1	0		1	0	0	1	1	
124	0.33	0	0	0	0	1		0	1	0	0		1	1	-	1	0	
20	0.34	1	0	1	0	0		0	1	0	0		1	1	-	1	1	
4b	0.39	0	0	1	0	1		1	0	1	1		1	1	1	1	1	
6a	0.46	0	0	1	0	1		1	0	1	1		1	1	1	1	0	
4a	0.52	0	0	1	1	1		1	0	1	1		1	1	1	1	1	
5a	0.52	0	0	1	0	0		1	0	1	1		1	1	1	1	0	
6b	0.57	0	0	1	0	1		1	0	1	0		1	1	1	1	0	
5b	0.66	0	0	1	0	1		1	0	1	1		1	1	1	1	0	
4c	1.05	0	0	1	0	0		1	0	1	1		1	1	1	1	1	
31	1.92	0	0	0	0	0		1	1	0	1		1	1	1	0	0	
F		7	9	5	14	3		1	3	1	1		15	14	17	19	0	
Σ/N		3/43	0/43	12/43	3/43	21/43		23/43	4/43	23/43	6/43		34/43	35/43	14/23	33/43	17/43	
%		7.0	0	27.9	7.0	48.8		53.5	9.3	53.5	14.0		79.1	81.4	60.9	76.7	39.5	

FIGURE 5-2. RAW DATA SHEET - SAMPLE A, ULTRASONIC SHEAR WAVE SCANS (Continued)

Flaw ID	Flaw Size	1202	1301	1307	1311	1312	1320	1322	1401	1501	1503	1611	1612
		Technician ID											
77a	0.09	0	0	0	1	0	0	0	0	0	0	1	-
122	0.09	0	0	0	0	1	0	0	0	0	0	0	-
132	0.10	0	0	0	0	0	0	0	1	0	0	1	-
121	0.10	0	0	1	0	1	0	0	0	0	0	0	-
75	0.10	0	0	0	0	0	0	0	1	0	0	1	-
76b	0.12	0	0	0	0	0	0	1	0	0	0	1	-
80	0.12	0	0	0	0	0	0	1	0	0	0	1	-
77b	0.13	0	0	0	0	0	1	0	1	0	0	1	-
79d	0.13	0	0	0	0	0	0	0	0	0	0	1	-
125	0.13	0	0	0	0	0	0	0	0	0	0	1	-
133	0.14	0	0	0	0	0	0	0	0	0	0	0	-
12a	0.15	0	0	0	0	0	0	0	0	0	0	0	-
78	0.16	0	0	0	0	0	0	1	0	0	0	1	-
9b	0.16	0	0	0	0	0	0	1	1	0	0	0	-
131	0.16	0	0	0	0	0	0	0	0	0	0	1	-
7	0.16	0	0	0	0	0	0	0	0	0	0	0	-
8a	0.17	0	0	0	0	0	0	0	0	0	0	0	-
130	0.19	0	0	0	1	0	1	0	0	0	0	1	-
10d	0.19	0	0	1	0	1	0	1	0	0	0	1	-
101	0.20	0	0	1	1	0	0	0	0	1	0	0	-
76a	0.21	1	0	0	0	1	1	1	0	0	0	0	-
81b	0.21	0	0	0	0	0	1	1	0	1	0	1	-
123	0.21	0	0	0	0	0	0	1	0	0	0	1	-
8c	0.21	0	0	1	0	0	0	0	0	0	0	1	-
9a	0.22	0	0	0	0	0	0	1	0	0	0	1	-
11b	0.22	0	0	1	0	1	1	0	1	0	0	1	-
79a	0.23	0	0	0	1	1	1	1	1	0	0	0	-
12b	0.23	0	0	0	0	1	0	0	0	0	0	1	-
8b	0.23	0	0	1	0	0	0	0	0	0	0	0	-
10a	0.24	0	0	1	0	1	1	1	0	0	0	1	-
81a	0.25	0	0	0	1	1	1	1	0	0	0	0	-
11a	0.29	1	1	1	1	1	1	0	1	0	0	0	-
10b	0.31	0	0	1	0	1	1	1	0	0	0	1	-
124	0.33	0	0	0	0	0	1	1	1	1	0	1	-
20	0.34	0	0	0	0	0	1	1	1	0	0	1	-
4b	0.39	1	1	1	1	1	1	1	1	0	1	1	-
6a	0.46	1	1	1	1	1	1	1	1	1	0	0	-
4a	0.52	1	1	1	1	1	1	1	1	0	1	1	-
5a	0.52	0	1	1	1	1	1	1	1	1	0	0	-
6b	0.57	1	1	1	1	1	1	1	1	1	0	0	-
5b	0.66	0	1	1	1	1	1	1	1	0	0	0	-
4c	1.05	1	1	1	1	1	1	1	1	1	1	1	-
31	1.92	0					1						
F		1	1	37	11	1	10	3	70	5	8	279	3
Σ/N		7/43	8/42	16/42	13/42	18/42	20/43	22/42	16/42	7/42	3/42	25/42	0/0
%		16.3	19.0	38.1	31.0	42.9	47.6	52.4	38.1	16.7	7.1	59.5	0

FIGURE 5-2. RAW DATA SHEET - SAMPLE A, ULTRASONIC SHEAR WAVE SCANS (Continued)

Flaw ID	Flaw Size	Technician ID 1644	1645	16E24	1701	1802	1808	1815	1816	1818	1822	2001	2004	2007
77a	0.09	0	0	0	0	–	1	0	0	1	0	1	0	0
122	0.09	0	0	0	0	1	0	1	1	1	0	1	1	0
132	0.10	0	0	0	1	–	1	0	0	1	0	0	0	0
121	0.10	0	0	1	0	0	0	1	0	1	0	0	0	0
75	0.10	0	0	0	0	–	1	0	1	1	0	0	1	0
76b	0.12	0	1	0	0	–	0	0	1	1	1	1	0	0
80	0.12	0	0	0	1	–	1	0	0	0	0	1	0	0
77b	0.13	0	1	0	1	–	0	0	0	1	1	1	1	0
79d	0.13	0	0	0	1	–	1	0	0	0	1	0	0	0
125	0.13	0	1	0	0	–	0	0	0	1	1	0	0	0
133	0.14	0	0	0	0	1	0	1	0	1	0	0	0	0
12a	0.15	0	0	0	0	1	1	0	0	0	0	0	0	0
78	0.16	0	0	0	0	–	0	0	0	1	0	1	0	0
9b	0.16	0	0	0	0	–	1	1	0	1	0	0	0	0
131	0.16	0	0	0	1	–	0	1	0	1	0	0	0	0
7	0.16	0	0	0	0	0	0	0	0	0	0	0	0	0
8a	0.17	0	0	0	0	0	0	0	0	0	1	0	0	0
130	0.19	0	1	0	1	–	1	1	0	1	0	0	1	0
10d	0.19	0	0	0	0	0	1	1	1	1	0	0	0	0
101	0.20	0	0	0	1	1	0	1	0	0	0	1	1	0
76a	0.21	0	1	1	1	–	0	0	0	1	1	1	1	0
81b	0.21	0	0	0	1	–	1	0	0	1	0	1	0	0
123	0.21	0	1	1	0	–	1	0	0	0	1	1	0	1
8c	0.21	0	0	0	0	0	1	1	0	1	1	1	0	0
9a	0.22	0	0	0	1	–	1	0	0	1	1	1	0	0
11b	0.22	1	1	1	0	0	0	0	0	1	0	0	0	0
79a	0.23	0	0	0	0	–	0	0	1	0	0	0	0	0
12b	0.23	0	0	1	1	1	0	1	0	1	0	0	0	0
8b	0.23	0	0	0	0	0	1	1	0	1	1	0	1	0
10a	0.24	1	0	0	1	1	0	1	0	1	1	1	1	0
81a	0.25	0	0	0	0	–	0	0	0	1	0	0	1	0
11a	0.29	1	1	1	0	1	1	0	1	1	0	1	1	0
10b	0.31	1	1	0	0	0	0	0	0	1	1	1	0	0
124	0.33	0	1	1	1	–	1	1	0	0	0	1	1	1
20	0.34	0	1	0	1	–	1	0	1	1	1	0	0	0
4b	0.39	0	1	1	1	1	1	1	1	1	1	1	1	0
6a	046	1	1	1	1	1	1	1	0	1	1	1	1	0
4a	0.52	1	1	1	0	1	1	1	1	1	1	1	1	0
5a	0.52	1	1	0	0	1	1	0	1	1	0	1	0	0
6b	0.57	1	1	1	1	1	1	1	1	1	1	1	1	0
5b	0.66	1	1	0	0	1	1	1	1	1	0	1	1	0
4c	1.05	0	1	1	0	1	1	1	1	1	1	1	1	0
31	1.92	–	.	–	–	–	–	–	–	–	–	–	–	–
F		2	37	0	58	4	14	302	86	6	22	13	68	10
E/N		9/42	18/42	12/42	17/42	14/22	24/42	19/42	13/42	33/42	18/42	[illegible]/42	17/42	2/42
%		21.4	[illegible]	28.6	40.5	63.6	57.1	45.2	31.0	78.6	42.9	54.8	40.5	4.8

FIGURE 5-2. RAW DATA SHEET - SAMPLE A, ULTRASONIC SHEAR WAVE SCANS (Continued)

Flaw ID	Flaw Size	Technician ID															
		2101	2106		2207											Σ/n	%
77a	0.09	0	0		1											13/53	24.5
122	0.09	1	0		1											15/54	27.8
132	0.10	0	0		1											12/53	22.6
121	0.10	0	0		1											8/54	14.8
75	0.10	0	0		1											15/55	27.3
76b	0.12	0	0		1											17/53	32.1
80	0.12	0	0		1											11/52	21.2
77b	0.13	0	1		1											20/53	37.7
79d	0.13	0	0		1											11/53	20.8
125	0.13	0	1		1											12/53	22.6
133	0.14	0	0		0											7/55	12.7
12a	0.15	0	0		1											5/54	9.3
78	0.16	1	0		1											17/53	32.1
9b	0.16	0	1		1											16/54	29.6
131	0.16	0	0		1											12/53	22.6
7	0.16	0	0		0											1/54	1.9
8a	0.17	0	0		1											6/54	11.1
130	0.19	0	0		1											21/53	39.6
10d	0.19	0	0		1											12/54	22.2
101	0.20	0	0		1											10/55	18.2
76a	0.21	0	0		1											24/53	45.3
81b	0.21	0	1		1											24/53	45.3
123	0.21	0	1		1											23/53	43.4
8c	0.21	0	1		1											15/54	27.8
9a	0.22	0	1		1											22/54	40.7
11b	0.22	0	1		1											22/54	40.7
79a	0.23	0	0		1											14/53	26.4
12b	0.23	0	1		1											18/54	33.3
8b	0.23	0	0		1											12/54	22.2
10a	0.24	0	0		1											27/54	50.0
81a	0.25	0	0		1											16/53	30.2
11a	0.29	0	0		1											29/53	54.7
10b	0.31	0	0		1											21/54	38.9
124	0.33	0	1		1											27/53	50.9
20	0.34	0	0		1											21/53	39.6
4b	0.39	1	1		1											45/54	83.3
6a	0.46	1	1		1											43/54	79.6
4a	0.52	1	1		1											45/54	83.3
5a	0.52	1	0		1											34/55	61.8
6b	0.57	1	1		1											43/54	79.6
5b	0.66	1	1		1											37/55	57.3
4c	1.05	1	1		1											43/54	79.6
31	1.92																
F		25	5		5												
Σ/N		9/42	16/42		40/42												
%		21.4	[illegible]		95.2												

FIGURE 5-2. RAW DATA SHEET - SAMPLE A, ULTRASONIC SHEAR WAVE SCANS (Continued)

Flaw ID	Flaw Size	Technician ID														
		13XX	1527		1623		1801								Σ/N	%
77a	0.09	1	1		0		1								3/4	75.0
122	0.09	1	1		–		1								3/3	100.0
132	0.10	0	1		1		1								3/4	75.0
121	0.10	1	1		–		1								3/3	100.0
75	0.10	1	1		1		1								4/4	100.0
76b	0.12	0	1		0		1								2/4	50.0
80	0.12	0	1		–		–								1/2	50.0
77b	0.13	1	0		0		0								1/4	25.0
79d	0.13	0	1		1		1								3/4	75.0
125	0.13	1	0		1		1								3/4	75.0
133	0.14	0	-		1		–								0/1	0
12a	0.15	1	1		–		1								3/3	100.0
78	0.16	0	1		0		1								2/4	50.0
9b	0.16	0	0		1		1								2/4	50.0
131	0.16	1	1		–		–								2/2	100.0
7	0.16	0	-		–		–								0/1	0
8a	0.17	–	–		–		–								0/0	—
130	0.19	1	1		1		1								4/4	100.0
10d	0.19	1	1		–		–								2/2	100.0
101	0.20	–	0		0		–								0/2	0
76a	0.21	0	1		1		0								2/4	50.0
81b	0.21	0	1		1		1								3/4	75.0
123	0.21	1	0		1		0								2/4	50.0
8c	0.21	–	–		–		–								0/0	0
9a	0.22	0	1		0		1								2/4	50.0
11b	0.22	1	1		–		1								3/3	100.0
79a	0.23	1	1		0		1								3/4	75.0
12b	0.23	1	1		–		1								3/3	100.0
8b	0.23	–	–		–		–								0/0	—
10a	0.24	1	1		–		–								2/2	100.0
81a	0.25	1	1		1		1								4/4	100.0
11a	0.29	1	1		–		1								3/3	100.0
10b	0.31	1	1		–		–								2/2	100.0
124	0.33	1	0		0		0								1/4	25.0
20	0.34	1	0		0		1								2/4	50.0
4b	0.39	1	–		–		–								1/1	100.0
6a	0.46	1	1		–		–								2/2	100.0
4a	0.52	1	–		–		–								1/1	100.0
5a	0.52	1	1		0		–								2/3	66.7
6b	0.57	1	1		–		1								3/3	100.0
5b	0.66	1	1		0		–								2/3	66.7
4c	1.05	1	–		–		–								1/1	100.0
31	1.92						–								-	--
F		47	24		17		21									
Σ/N		27/38	[illegible]		11/22		21/25									
%		71.1	[illegible]		50.0		84.0									

FIGURE 5-3. RAW DATA SHEET - SAMPLE A, SEMI-AUTOMATIC ULTRASONIC SHEAR WAVE SCANS (Continued)

		TECHNICIAN ID																					
Flaw ID	Flaw Size	0201	0202	020?	0206	0208	0209		03E1	03E2	03E3	03E4	03E5	03E6	03E7	03E8	03E9	03E10	03E11	03E12	03E13	03E14
33b	.08	1	0	–	1	–	–		–	1	1	0	0	1	0	0	0	1	0	1	1	0
V-2a	0.10	1	–	1	–	1	0		0	1	0	1	0	0	0	0	1	1	0	1	1	1
29b	0.10	1	–	0	–	0	0		0	1	1	1	1	0	0	0	0	0	0	0	1	1
42a	0.10	1	1	–	0	–	–		–	1	1	0	0	0	1	0	0	0	0	1	1	1
25a	0.11	1	–	1	–	0	0		0	0	0	0	0	0	1	0	0	0	0	0	0	0
6b	0.12	0	0	–	0	–	–		–	1	0	0	0	0	0	1	1	0	1	0	0	0
1a	0.12	1	–	0	–	0	1		0		0	0	0	1	0	0	0	–	0	1	1	1
2b	0.12	1	–	0	–	0	0		0	–	0	1	1	0	1	0	0	–	0	1	1	1
36b	0.13	1	–	1	–	0	0		0	–	0	1	1	0	0	0	1	–	1	1	1	0
40a	0.14	0	0	–	0	–	–		–	1	1	1	1	0	0	0	1	1	0	1	0	0
31b	0.15	1	–	1	–	0	1		0	1	0	0	0	0	0	0	1	0	1	0	1	0
0-1b	0.15	1	–	1	–	0	1		0	1	1	1	0	0	1	1	1	1	1	1	1	1
29b	0.15	0	–	1	–	0	0		0	1	1	0	1	1	1	1	1	0	1	0	1	1
6c	0.15	0	0	–	0	–	–		–	1	0	0	0	0	0	1	1	1	1	0	0	0
4a	0.16	1	–	1	–	1	1		0	–	1	1	1	1	1	1	0	–	1	1	1	1
9b	0.17	1	1	–	1	–	–		–	1	1	1	0	0	0	1	1	1	1	1	1	1
31b	0.17	1	–	1	–	1	1		–	–	1	1	1	1	0	1	1	–	1	1	1	1
0-1a	0.18	1	–	1	–	0	1		0	1	1	0	0	0	0	1	1	1	1	0	1	1
38b	0.19	1	–	1	–	0	1		0	–	1	1	1	0	1	1	1	–	1	1	0	1
3a	0.20	1	–	0	–	1	1		0	–	1	1	1	0	1	1	0	–	1	1	0	1
5a	0.20	1	–	0	–	0	1		0	–	0	1	0	0	0	1	0	–	1	0	1	0
2a	0.21	1	–	1	–	1	0		–	–	1	1	0	0	0	1	1	–	1	1	1	1
8b	0.2?	1	–	1	–	0	1		0	1	1	1	1	1	0	1	0	1	1	1	1	1
20a	0.23	1	0	–	0	–	–		–	1	1	0	0	0	0	1	0	1	1	1	1	1
3b	0.25	1	–	1	–	1	1		0	–	0	1	1	0	1	1	1	–	1	1	1	1
25b	0.26	1	–	1	–	0	1		0	1	1	1	0	0	0	1	1	1	1	1	1	0
28b	0.27	0	1	–	0	–	–		–	1	1	1	0	0	0	1	1	1	1	1	1	0
9a	0.28	1	1	–	1	–	–		–	1	1	0	0	0	0	1	1	1	1	1	1	1
26b	0.29	1	0	–	0	–	–		–	1	1	0	0	0	1	1	0	1	1	1	1	1
23a	0.30	1	–	1	–	1	1		0	1	1	1	1	1	1	1	1	1	1	0	1	1
35a	0.30	1	1	–	1	–	–		–	1	1	1	1	0	0	1	1	1	1	1	0	1
34a	0.31	1	–	1	–	0	1		0	1	0	1	1	0	0	1	1	1	1	1	1	0
11b	0.32	1	–	1	–	1	1		–	–	1	1	1	1	0	1	1	1	1	1	1	1
30a	0.33	1	–	1	–	0	1		0	0	1	1	0	0	0	1	1	1	1	1	1	0
V-1a	0.33	1	–	1	–	0	1		0	–	1	1	1	1	1	1	1	1	1	1	1	1
12b	0.33	1	0	–	1	–	–		–	–	1	1	1	0	0	1	1	1	1	1	1	1
14b	0.33	1	0	–	1	–	–		–	–	1	1	1	1	0	1	1	–	1	1	1	1
30b	0.35	1	–	1	–	0	1		0	0	1	1	1	0	0	1	1	1	1	1	1	0
13b	0.35	1	–	1	–	1	0		–	–	1	1	0	1	0	1	1	–	1	1	1	1
6a	0.36	0	0	–	0	–	–		–	1	0	0	0	0	0	1	1	1	1	0	1	0
31a	0.36	1	–	1	–	1	1		–	–	0	1	0	0	0	1	1	–	1	1	1	1
6d	0.37	0	0	–	0	–	–		–	1	0	0	0	0	0	1	1	1	1	0	0	0
27b	0.37	1	–	1	–	1	0		–	–	1	1	0	0	0	1	1	–	1	1	1	1
28a	0.46	1	0	–	1	–	–		–	1	1	1	0	0	0	1	1	1	1	1	1	0
19a	0.50	1	–	1	–	1	0		–	–	1	1	1	1	0	1	1	–	1	1	1	1
8a	0.58	1	–	1	–	0	1		0	1	1	1	1	0	0	1	0	1	1	1	1	1
V-1b	0.60	1	–	1	–	0	1		0	–	1	1	1	1	1	1	1	1	1	1	1	1
11a	0.63	1	–	1	–	1	1		–	–	1	1	1	1	0	1	1	1	1	1	1	1
14a	0.65	1	0	–	1	–	–		–	–	1	1	0	0	0	1	1	–	1	1	1	1
12a	0.66	1	0	–	1	–	–		–	–	1	1	0	0	0	1	1	1	1	1	1	1
7a	0.72	1	0	–	–	–	–		–	1	0	0	0	0	0	1	1	1	1	1	1	1
7b	0.75	1	1	–	–	–	–		–	1	0	1	1	0	1	1	1	1	1	1	1	1
F		5	15	4	2	3	2		15	71	7	9	8	86	99	4	21	33	29	12	99	17
X/N		45/52	9/30	27/32	9/18	13/32	22/32		0/24	27/30	36/52	37/52	24/52	4/52	14/52	42/52	39/52	30/36	44/52	41/52	44/52	36/52
%		87	30	84	50	41	69		0	90	69	71	46	8	27	81	75	83	85	79	85	69

FIGURE 5-4. RAW DATA SHEET - SAMPLE B, EDDY CURRENT SURFACE SCANS, SPECIMENS BELOW

Flaw ID	Flaw Size	TECHNICIAN ID																				
		03E15	03E16	03E17	03E18	03E19	03E20		0401	0402	0403	0405	0408		0503	0504	0506	05010		0702	0703	0705
33h	.08	1	1	0	0	0	0		-	0	0	0	0		1	1	0	0		1	0	1
V-2a	0.10	1	1	0	1	0	0		-	0	1	0	0		0	1	0	1		1	0	1
29b	0.10	0	0	0	1	0	0		-	0	1	0	0		0	0	1	1		0	0	1
42a	0.10	1	1	1	1	1	0		-	1	0	0	1		1	1	0	0		1	1	1
25a	0.11	1	1	1	0	0	0		-	0	1	0	0		0	0	0	0		0	0	1
6b	0.12	1	1	0	0	1	1		-	0	0	0	0		1	1	0	0		0	0	0
1a	0.12	0	0	0	1	0	0		1	0	1	0	0		1	1	0	0		1	0	1
2b	0.12	0	0	0	1	0	0		1	0	0	0	0		1	1	0	0		0	0	1
36b	0.13	1	1	1	1	1	0		-	0	1	0	0		1	1	0	0		1	0	1
40a	0.14	1	1	1	1	1	0		-	0	1	0	0		1	1	1	1		0	0	1
34b	0.15	1	1	1	0	1	0		-	1	1	0	1		0	1	0	1		0	0	1
U-1b	0.15	1	1	1	1	1	1		-	0	1	1	0		1	0	0	1		1	0	1
29b	0.15	1	1	1	1	1	1		-	0	1	1	1		1	1	0	0		1	0	1
6c	0.15	1	1	0	0	1	1		-	0	0	0	0		1	1	0	0		0	0	0
4a	0.16	1	1	0	1	1	0		1	1	0	0	1		1	1	0	1		1	0	1
9b	0.17	1	1	0	1	1	1		-	1	1	0	1		0	1	0	1		1	0	1
31b	0.17	1	1	1	1	1	1		1	1	1	0	1		1	1	1	1		0	1	1
U-1a	0.18	1	1	1	1	1	1		-	1	1	1	0		1	0	0	1		1	1	1
35b	0.19	1	1	1	1	1	0		-	1	1	0	1		1	0	0	1		1	1	1
3a	0.20	1	1	0	1	1	0		1	1	0	1	1		1	1	1	1		0	1	1
5a	0.20	1	1	1	1	1	0		1	1	1	0	1		0	1	0	1		1	0	1
27a	0.21	1	1	0	1	1	1		1	1	1	0	0		1	1	1	1		0	0	1
8b	0.23	1	1	0	0	0	1		-	1	1	1	1		1	1	1	1		1	1	1
26a	0.23	1	1	1	1	1	1		-	1	1	0	1		1	1	0	1		1	1	1
3b	0.23	1	1	1	1	1	0		1	1	0	0	0		1	1	0	1		1	1	1
25b	0.26	1	1	1	1	1	1		-	1	1	1	1		1	0	0	1		1	1	1
28b	0.27	1	1	1	1	1	0		-	1	1	0	1		1	1	0	1		1	1	1
9a	0.28	1	1	1	1	1	1		-	1	1	1	1		1	1	0	1		1	0	1
26b	0.29	1	1	1	1	1	1		-	1	1	0	1		1	1	0	1		1	1	1
23a	0.30	0	1	0	1	1	1		-	1	1	1	1		1	1	1	1		1	0	1
33a	0.30	1	1	0	1	1	1		-	1	1	0	1		1	1	1	1		1	1	1
34a	0.31	1	1	1	1	1	0		-	1	1	1	1		0	1	1	1		0	1	1
11b	0.32	1	1	1	1	1	1		-	1	1	1	1		1	1	1	1		1	1	1
30a	0.33	1	1	1	1	1	1		-	1	1	1	1		1	1	1	1		1	1	1
V-1a	0.33	1	1	1	1	1	1		-	1	1	0	1		1	1	1	1		0	1	1
12b	0.33	1	1	1	1	1	1		1	1	1	1	1		1	1	1	1		0	1	1
14b	0.33	1	1	1	1	1	1		1	1	1	1	1		1	1	1	1		0	1	1
30b	0.35	1	1	1	0	1	1		-	1	1	1	1		1	1	1	1		1	1	1
18b	0.35	1	1	1	1	1	1		1	1	1	1	1		1	1	1	1		1	1	1
6a	0.36	1	0	1	0	1	1		-	1	1	0	0		1	1	0	0		0	0	0
31a	0.36	1	1	1	1	0	1		1	1	1	1	1		1	0	1	1		1	1	1
6d	0.37	1	0	0	1	1	1		-	0	1	0	0		1	1	0	0		0	0	0
27b	0.37	1	1	0	1	0	1		1	1	1	0	0		1	1	1	1		0	0	1
28a	0.46	1	1	1	0	1	1		-	1	1	1	1		1	1	0	1		1	1	1
13a	0.58	1	1	1	1	1	1		1	1	1	1	1		1	1	1	1		1	1	1
8a	0.58	1	1	0	1	0	1		-	1	1	1	1		1	1	0	1		1	0	1
V-1b	0.60	1	1	1	1	1	1		-	1	1	0	1		1	1	1	1		0	1	1
11a	0.63	1	1	1	1	1	1		-	1	1	1	1		1	1	1	1		1	0	1
14a	0.65	1	1	1	1	1	1		1	1	1	1	1		1	1	1	1		1	1	1
12a	0.66	1	1	0	1	1	1		1	1	1	1	1		1	1	1	1		0	1	1
7a	0.72	1	1	1	1	1	1		-	1	1	0	1		1	0	1	1		1	1	1
7b	0.75	1	1	1	1	1	1		-	1	1	1	1		1	1	1	1		1	1	1
F		6	29	19	72	35	50		96	11	6	2	1		30	15	29	1		36	9	3
Z/N		48/52	47/52	34/52	43/52	42/52	35/52		16/16	39/52	44/52	23/52	35/52		45/52	44/52	25/52	41/52		33/52	28/52	48/52
%		92	90	65	83	81	67		100	75	85	44	67		87	85	48	79		63	54	92

FIGURE 5-4. RAW DATA SHEET - SAMPLE B, EDDY CURRENT SURFACE SCANS, SPECIMENS BELOW (Continued)

TECHNICIAN ID

Flaw ID	Flaw Size	0801	0803	0804	0807	0901	0903	0905	0907	0909	0912	0913	1006	1009	1013	1016	1036
33b	.08	-	0	0	1	0	0	1	-	0	1	1	1	0	0	0	0
V-2a	0.10	-	0	0	1	1	0	0	0	0	1	1	1	0	0	0	1
29b	0.10	-	0	0	1	0	0	1	-	1	1	1	1	0	0	0	0
42a	0.10	-	0	0	1	0	0	0	-	1	1	1	1	0	0	0	1
25a	0.11	-	0	0	1	1	0	1	0	0	0	1	0	0	0	0	0
6b	0.12	-	0	0	0	0	1	1	-	1	0	0	1	0	0	0	0
1a	0.12	0	0	0	1	0	0	0	-	0	0	0	0	0	1	0	1
2b	0.12	0	0	0	0	0	0	0	-	0	0	0	1	0	0	0	1
36b	0.13	-	1	0	1	1	1	0	1	0	1	1	0	1	0	1	1
40a	0.14	-	0	0	0	1	0	1	-	0	1	-	1	0	0	0	0
34b	0.15	-	0	0	1	1	1	1	-	0	1	1	1	0	0	0	1
U-1b	0.15	-	0	0	1	1	0	1	0	0	1	0	1	1	0	0	1
29b	0.15	-	1	0	1	0	0	1	0	0	1	-	1	1	1	0	1
6c	0.15	-	0	0	0	0	1	1	-	0	0	0	1	0	0	0	0
4a	0.16	1	0	1	0	1	1	0	-	1	1	1	1	0	0	1	1
[illegible]	0.17	-	1	1	1	0	0	1	-	1	1	1	1	1	1	0	1
31b	0.17	-	1	1	1	0	1	1	0	0	1	0	1	1	1	1	1
U-1a	0.18	-	1	0	1	1	1	1	0	1	1	0	1	1	0	0	1
35b	0.19	-	1	1	1	1	1	1	0	1	1	1	0	1	0	1	0
3a	0.20	1	1	1	0	0	0	0	-	1	1	0	1	0	0	0	1
5a	0.20	1	1	1	1	1	1	0	-	1	1	1	1	1	0	1	1
27a	0.21	-	1	1	1	0	1	1	0	0	1	0	1	1	1	1	1
8b	0.23	-	1	1	0	1	0	1	1	1	1	0	1	1	0	0	0
26a	0.23	-	1	1	0	1	1	1	-	1	1	1	1	1	0	1	1
3b	0.23	1	1	0	0	0	0	0	-	1	1	1	1	1	1	1	1
25b	0.26	-	0	0	1	1	1	1	0	1	1	1	1	1	1	0	1
28b	0.27	-	0	1	1	1	1	1	-	0	1	0	0	1	1	1	1
9a	0.28	-	1	1	1	0	0	1	-	1	1	1	1	0	1	1	1
26b	0.29	-	1	1	0	1	1	1	-	1	1	1	1	1	0	0	1
23a	0.30	-	1	1	1	1	1	1	0	0	1	1	1	1	0	0	1
33a	0.30	-	1	1	1	0	0	1	-	0	1	1	1	0	1	0	1
34a	0.31	-	0	0	1	1	1	1	-	0	1	1	1	1	0	1	1
11b	0.32	-	1	1	1	1	1	1	1	0	1	0	1	1	1	1	0
30a	0.33	-	0	0	1	1	1	1	-	0	1	0	1	1	1	1	1
V-1a	0.33	-	1	0	1	1	1	1	-	1	1	1	1	1	1	0	1
12b	0.33	--	1	1	1	1	1	1	1	0	1	0	1	1	1	1	1
14b	0.33	-	1	1	1	1	1	1	1	0	1	0	1	1	1	1	1
30b	0.35	-	0	0	1	1	1	1	-	0	1	0	1	1	1	1	1
13b	0.35	-	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1
6a	0.36	-	0	0	0	0	1	1	-	0	0	0	0	0	0	0	1
31a	0.36	-	1	1	1	0	1	1	0	0	1	0	1	1	1	1	1
6d	0.37	-	0	0	0	0	1	1	-	0	0	0	0	0	0	0	0
27b	0.37	-	1	1	1	0	0	1	0	0	1	0	1	1	1	1	1
28a	0.46	-	1	1	1	1	1	1	-	1	1	0	0	1	1	1	1
13a	0.58	-	1	1	1	1	1	1	1	0	1	0	1	1	1	1	1
8a	0.58	-	1	1	0	1	0	1	1	1	1	1	1	0	0	0	1
V-1b	0.60	-	1	0	1	1	1	1	-	1	1	1	1	1	1	0	1
11a	0.63	-	1	1	1	1	1	1	1	0	1	0	1	1	1	1	0
14a	0.65	-	1	1	1	1	1	1	1	0	1	0	1	1	1	1	1
12a	0.66	-	0	1	1	1	1	1	1	0	1	0	1	1	1	1	0
7a	0.72	-	1	0	1	1	1	1	-	0	1	1	1	1	1	1	1
7b	0.75	-	1	0	1	1	1	1	-	0	1	1	1	1	1	1	1
F		7	0	43	8	55	2	9	0	13	2	99	2	1	1	0	26
Σ/N		4/6	31/52	26/52	39/52	33/52	34/52	43/52	11/23	20/52	45/52	24/50	44/52	34/52	27/52	26/52	40/52
%		67	60	50	75	63	65	83	48	38	87	48	85	65	52	50	77

FIGURE 5-4. RAW DATA SHEET - SAMPLE B, EDDY CURRENT SURFACE SCANS, SPECIMENS BELOW (Continued)

		TECHNICIAN ID																	
Flaw ID	Flaw Size	1113	1118	1121	1201	1203	1204	1205	1301	1302	1311	1312	1315	1322	1307	1314	1325	1406	1403
33b	.08	1	1	0	-	0	1	0	0	1	1	1	1	0	1	1	0	0	1
V-2a	0.10	1	1	0	0	-	0	0	0	0	0	1	1	0	0	0	0	1	1
29b	0.10	1	1	0	-	-	1	1	0	1	1	0	1	0	1	1	0	0	0
42a	0.10	1	1	1	-	0	0	0	0	0	1	0	1	0	1	1	0	1	0
25a	0.11	1	1	1	1	-	0	1	0	0	0	0	0	0	0	0	0	1	1
6b	0.12	1	1	1	-	0	0	0	0	1	0	0	1	0	0	0	0	0	1
1a	0.12	1	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2b	0.12	1	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
36b	0.13	1	1	1	-	-	1	1	1	1	1	1	0	1	1	1	0	1	1
40a	0.14	0	0	0	-	-	1	1	0	0	0	1	1	0	1	1	0	0	1
34b	0.15	1	1	1	-	-	1	1	1	1	1	1	1	0	1	1	0	1	1
U-1b	0.15	1	1	1	1	-	1	1	1	1	0	1	1	0	0	0	0	0	1
29b	0.15	1	1	1	0	-	1	0	0	1	1	1	1	1	0	0	1	1	1
6c	0.15	1	1	1	-	0	0	0	0	1	0	0	1	0	0	0	0	0	1
4a	0.16	1	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9b	0.17	1	1	1	-	1	1	0	0	1	1	1	1	0	1	1	0	0	1
31b	0.17	1	1	1	-	-	1	1	1	1	1	-	1	0	0	0	1	1	1
U-1a	0.18	1	1	1	1	-	1	1	1	1	0	1	1	1	1	1	0	0	1
35b	0.19	1	1	1	-	-	1	0	1	0	1	1	0	0	1	1	1	1	1
3a	0.20	1	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5a	0.20	1	1	1	-	-	-	-		-	-	-	-	-	-		-	-	-
27a	0.21	1	1	1	-	-	1	1	1	1	1	-	0	1	1	1	1	1	1
8b	0.23	1	0	1	1	-	0	1	0	0	0	1	1	1	1	1	0	1	1
26a	0.23	1	1	1	-	0	1	1	1	1	1	1	1	0	1	1	0	1	1
3b	0.23	1	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
25b	0.26	1	1	1	1	-	1	1	1	1	1	1	1	1	1	1	1	1	1
28b	0.27	1	1	1	-	-	1	1	1	0	1	1	1	1	1	1	0	1	1
9a	0.28	1	1	1	-	1	1	0	1	1	1	0	1	1	1	1	1	1	1
26b	0.29	1	1	1	-	0	1	1	1	1	1	1	1	0	1	1	0	1	1
23a	0.30	1	1	1	0	-	1	1	1	1	1	1	1	0	1	1	0	1	1
33a	0.30	1	1	1	-	0	1	1	1	1	1	1	1	0	1	1	1	0	1
34a	0.31	1	1	1	-	-	1	1	1	1	1	1	1	0	1	1	0	1	1
11b	0.32	1	1	0	-	0	1	1	1	1	1	-	1	1	1	1	0	1	1
30a	0.33	1	1	1	-	-	1	1	1	1	1	1	1	0	1	1	0	1	1
V-1a	0.33	1	1	1	-	-	1	1	1	1	1	0	1	1	1	1	1	1	1
12b	0.33	1	1	0	-	-	1	1	1	1	1	-	1	1	1	1	1	1	1
14b	0.33	1	1	1	-	-	1	1	1	1	1	-	1	1	1	1	1	1	1
30b	0.35	1	1	1	-	-	1	1	1	1	1	1	1	0	1	1	0	1	1
18b	0.35	1	0	1	-	-	1	1	1	1	1	-	1	1	1	1	1	1	1
6a	0.36	1	0	1	-	0	0	0	0	0	0	0	1	0	0	0	0	0	1
31a	0.36	1	1	1	-	-	1	1	0	1	1	-	1	0	0	0	1	1	1
6d	0.37	1	0	1	-	0	0	0	0	0	0	0	1	0	0	0	0	0	1
27b	0.37	1	1	1	-	-	1	1	1	1	1	-	0	1	1	1	1	1	1
28a	0.46	1	1	1	-	-	1	1	1	0	1	1	1	1	1	1	0	1	1
13a	0.58	1	0	1	-	-	1	1	1	1	1	-	1	1	1	1	1	1	1
8a	0.58	1	0	1	1	-	0	1	1	1	0	1	1	1	1	1	0	1	1
V-1b	0.60	1	1	1	-	-	1	1	1	1	1	0	1	1	1	1	1	1	1
11a	0.63	1	1	0	-	0	1	1	1	1	1	-	1	0	1	1	0	1	1
14a	0.65	1	1	1	-	-	1	1	1	1	1	-	1	1	1	1	1	1	1
12a	0.66	1	1	0	-	-	1	1	1	1	1	-	1	1	1	1	1	1	1
7a	0.72	1	1	1	-	0	1	1	1	1	1	1	1	0	1	1	1	1	1
7b	0.75	1	1	1	-	0	1	1	1	1	1	1	1	1	1	1	1	1	1
F		8	35	23	1	29	2	15	6	5	99	10	3	2	5	5	7	2	2
Σ/N		[illegible]	[illegible]	[illegible]	6/9	2/15	37/46	35/46	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	35/46	[illegible]
%		98	87	85	67	13	80	76	70	78	76	71	89	46	78	78	41	76	96

FIGURE 5-4. RAW DATA SHEET - SAMPLE B, EDDY CURRENT SURFACE SCANS, SPECIMENS BELOW (Continued)

Flaw ID	Flaw Size	1503	16E1	16E21	16E4	16E6	16D1E	1701	1804	1805	1806	1807	1810	1811	1813	2002	2004	2005
		TECHNICIAN ID																
33b	.08	1	0	0	0	1	1	1	0	1	0	1	0	1	0	0	1	0
V-2a	0.10	-	0	1	0	1	0	1	0	1	0	1	0	0	1	1	0	0
29b	0.10	0	0	1	0	1	1	1	1	1	1	1	0	0	0	0	0	0
42a	0.10	0	0	1	0	0	1	1	1	1	1	1	0	0	0	0	0	0
25a	0.11	-	1	0	1	1	0	0	0	1	1	0	1	1	0	1	0	1
6b	0.12	1	1	1	1	1	1	0	1	1	0	0	0	0	0	0	1	0
1a	0.12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2b	0.12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
36b	0.13	1	1	0	1	1	1	0	1	1	1	1	1	1	1	0	1	0
40a	0.14	0	0	1	0	0	1	0	1	1	1	0	0	0	0	1	1	0
34b	0.15	1	0	0	1	1	1	[illegible]	1	1	1	0	0	0	1	1	1	0
U-1b	0.15	-	1	1	1	1	1	0	0	1	0	1	1	0	1	1	1	0
29b	0.15	-	1	1	0	1	1	1	1	1	1	1	0	0	1	0	1	0
6c	0.15	1	1	1	1	1	1	0	1	1	0	0	0	0	0	0	1	1
4a	0.16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9b	0.17	1	1	1	1	1	0	0	1	1	0	1	0	1	0	1	1	0
31b	0.17	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	0
U-1a	0.18	-	1	1	1	1	1	0	0	1	0	1	1	0	1	1	1	1
35b	0.19	1	1	1	1	1	1	0	1	1	0	1	1	0	1	1	1	0
3a	0.20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5a	0.20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
27a	0.21	1	1	1	1	1	1	1	1	0	0	0	0	1	1	1	0	0
8b	0.23	-	1	1	0	1	1	1	1	1	1	1	0	0	1	0	1	0
26a	0.23	0	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	0
3b	0.23	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
25b	0.26	-	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	0
28b	0.27	0	-	1	1	1	1	0	1	1	0	1	0	0	1	1	1	0
9a	0.28	1	-	1	1	1	0	1	1	1	0	0	0	1	0	1	1	1
26b	0.29	0	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1
23a	0.30	-	1	1	1	1	0	1	1	1	1	1	0	1	0	0	1	0
33a	0.30	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1	0
34a	0.31	1	0	0	1	1	1	0	1	1	1	0	0	0	1	1	1	1
11b	0.32	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0
30a	0.33	1	0	1	0	1	1	0	1	1	1	0	1	0	1	1	1	0
V-1a	0.33	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
12b	0.33	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0
14b	0.33	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0
30b	0.35	1	0	1	0	1	1	0	1	1	1	0	0	0	1	1		1
18b	0.35	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	0
6a	0.36	1	1	1	1	1	1	0	0	1	0	0	[illegible]	0	0	0	0	0
31a	0.36	1	1	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1
6d	0.37	1	1	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0
27b	0.37	1	1	1	1	1	1	1	1	0	0	0	1	1	1	1	0	0
28a	0.46	1	0	1	1	1	1	0	1	1	0	1	1	0	1	1	1	0
13a	0.58	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	0
8a	0.58	-	1	1	0	1	1	0	1	1	1	1	0	0	1	1	1	1
V-1b	0.60	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0
11a	0.63	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	0
14a	0.65	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	0
12a	0.66	0	1	1	1	1	1	0	1	1	1	1	0	1	1	1	1	0
7a	0.72	1	1	1	1	1	0	0	1	1	1	0	1	0	1	1	0	0
7b	0.75	1	1	1	1	1	0	0	1	1	0	0	1	0	1	1	1	0
F		0	6	5	2	3	8	30	20	164	379	50	6	6	40	18	44	122
X/N		30/37	33/44	40/46	36/46	44/46	39/46	24/46	39/46	41/46	24/46	24/46	22/46	24/46	33/46	35/46	37/46	8/46
%		81	73	87	78	96	85	52	85	89	52	52	48	52	72	76	80	17

FIGURE 5-4. RAW DATA SHEET - SAMPLE B, EDDY CURRENT SURFACE SCANS, SPECIMENS BELOW (Continued)

		TECHNICIAN ID								
Flaw ID	Flaw Size	2011	2044	2102	2103	2204	2205	2207	Σ/N	%
33b	.08	0	0	1	-	0	1	-	39/86	45.3
V-2a	0.10	0	0	1	0	1	0	1	41/90	45.6
29b	0.10	0	0	1	1	0	0	-	37/88	42.0
42a	0.10	1	1	1	-	0	0	-	44/86	51.2
25a	0.11	0	1	1	0	0	1	1	32/90	35.6
6b	0.12	0	1	1	-	0	1	-	32/86	37.2
1a	0.12	-	-	-	-	-	-	-	19/52	36.5
2b	0.12	-	-	-	-	-	-	-	17/52	32.7
36b	0.13	1	1	1	-	0	1	1	60/87	69.0
40a	0.14	0	0	1	0	0	0	-	37/81	45.7
34b	0.15	1	1	1	1	0	1	-	54/[illegible]	61.4
U-1b	0.15	0	1	1	0	1	1	1	60/90	66.7
29b	0.15	0	0	1	0	1	1	1	53/81	65.4
6c	0.15	0	1	1	-	0	1	-	31/78	39.7
4a	0.16	-	-	-	-	-	-	-	39/52	75.0
9b	0.17	0	1	1	-	0	1	-	62/86	72.1
31b	0.17	1	1	1	1	0	1	-	72/86	83.7
U1a	0.18	1	1	1	0	1	1	1	67/90	74.4
35b	0.19	1	1	1	-	0	1	0	65/87	74.7
3a	0.20	-	-	-	-	-	-	-	35/52	67.3
5a	0.20	-	-	-	-	-	-	-	35/53	66.0
27a	0.21	0	1	1	1	0	1	-	64/86	74.4
8b	0.23	0	0	1	1	1	1	1	64/90	71.1
26a	0.23	0	1	1	-	1	1	-	66/86	76.7
3b	0.23	-	-	-	-	-	-	-	39/72	54.2
25b	0.26	0	1	1	0	1	1	1	74/89	83.1
28b	0.27	1	1	1	1	1	1	-	64/85	75.3
9a	0.28	1	1	1	-	0	0	-	66/85	77.6
26b	0.29	1	1	1	-	1	1	-	68/88	77.3
23a	0.30	1	1	1	0	1	1	1	72/90	80.0
39a	0.30	1	0	1	-	0	1	-	68/86	79.1
34a	0.31	1	1	1	1	1	1	-	67/88	76.1
11b	0.32	1	1	1	-	1	1	1	79/87	90.8
30a	0.33	1	1	1	1	1	1	-	69/88	78.4
V-1a	0.33	1	1	1	1	1	1	-	79/87	90.8
12b	0.33	1	1	1	-	0	1	1	77/86	89.5
14b	0.33	1	1	1	-	0	1	-	77/84	91.7
30b	0.35	1	1	1	1	1	1	-	69/88	78.4
13b	0.35	1	1	1	1	0	1	-	77/86	89.5
6a	0.36	0	0	1	-	0	1	-	30/86	34.9
31a	0.36	0	1	1	1	0	1	-	66/86	76.7
6d	0.37	0	0	1	-	0	1	-	25/86	29.1
27b	0.37	1	1	1	1	0	1	-	63/86	73.3
28a	0.46	1	1	1	1	1	1	-	70/86	81.4
13a	0.58	0	1	1	1	0	1	-	76/86	88.4
8a	0.58	1	0	1	1	1	1	1	68/90	75.6
V-1b	0.60	1	1	1	1	1	1	-	78/87	89.7
11a	0.63	0	1	1	-	1	1	1	75/87	86.2
14a	0.65	0	1	1	-	0	1	-	74/84	88.1
12a	0.66	0	1	1	-	0	1	1	69/86	80.2
7a	0.72	1	1	1	-	1	1	-	67/85	78.8
7b	0.75	1	1	1	-	1	1	-	74/84	88.1
F		62	24	59	9	17	2	4		
Σ/N		29/46	36/46	46/46	17/25	21/46	41/46	14/15		
%		63	78	100	68	46	89	93		

FIGURE 5-4. RAW DATA SHEET - SAMPLE B, EDDY CURRENT SURFACE SCANS, SPECIMENS BELOW (Continued)

Flaw ID	Flaw Size	0202	0205	0206	0208	2209	03E6	03E8	3E12	3E14	0402	0403	0401	0702	Σ/N	%
		TECHNICIAN ID														
33b	.08	–	0	–	1	1	0	0	1	1	–	–	–	1	5/8	63
V-2a	0.10	0	–	1	–	–	0	0	–	1	–	0	0	0	2/8	25
29b	0.10	0	–	1	–	–	0	0	1	0	0	–	–	0	2/8	25
42a	0.10	–	0	–	1	0	0	0	1	1	–	–	–	1	4/8	50
25a	0.11	0	–	0	–	–	0	0	–	0	–	0	0	1	1/8	13
6b	0.12	–	0	–	0	0	0	0	0	0	–	–	–	0	0/8	0
1a	0.12	1	–	1	–	–	0	0	1	0	–	0	0	0	3/9	33
2b	0.12	0	–	1	–	–	0	1	0	0	–	0	0	1	3/9	33
36b	0.13	1	–	0	–	–	1	1	1	1	0	1	1	1	8/10	80
40a	0.14	–	0	–	0	1	1	1	1	1	0	–	–	0	5/9	56
34b	0.15	0	–	0	–	–	1	1	1	1	0	–	–	1	5/8	63
U-1b	0.15	0	–	0	–	–	0	1	–	0	–	1	1	1	4/8	50
29b	0.15	0	–	1	–	–	0	0	–	0	–	1	0	0	2/8	25
6c	0.15	–	0	–	0	0	0	0	0	0	–	–	–	0	0/8	0
4a	0.16	0	–	1	0	0	0	1	1	1	–	0	0	0	4/9	44
9b	0.17	–	1	–	1	1	1	1	1	1	–	–	–	0	7/8	88
31b	0.17	1	–	1	–	–	0	1	1	1	–	1	1	0	7/9	78
U-1a	0.18	0	–	0	–	–	0	1	–	0	–	1	1	1	4/8	50
35b	0.19	0	–	0	–	–	0	0	1	1	1	1	1	0	5/10	50
3a	0.20	1	–	1	–	–	1	1	1	1	–	0	0	0	6/9	66
5a	0.20	0	–	0	–	–	1	1	0	1	–	1	1	1	6/9	66
27a	0.21	1	–	1	–	–	0	1	1	1	–	1	1	0	7/9	78
8b	0.23	1	–	1	–	–	0	0	–	1	–	0	0	1	4/8	50
26a	0.23	–	0	–	0	1	1	1	1	1	–	–	–	1	6/8	75
3b	0.23	0	–	–	–	–	0	1	1	1	–	0	0	0	3/8	38
25b	0.25	0	–	0	–	–	1	1	–	0	–	1	1	1	5/8	63
28b	0.27	–	0	–	1	1	0	0	1	1	0	–	–	1	5/9	56
9a	0.28	–	1	–	1	1	0	1	1	1	–	–	–	0	6/8	75
26b	0.29	–	0	–	0	1	0	1	1	1	–	–	–	1	5/8	63
23a	0.30	1	–	0	–	–	0	1	–	0	–	0	1	0	3/8	38
39a	0.30	–	1	–	1	1	1	0	1	1	–	–	–	1	7/8	88
34a	0.31	0	–	0	–	–	1	1	1	1	1	–	–	1	6/8	75
11b	0.32	1	–	1	–	–	1	1	–	1	1	–	–	1	7/7	100
30a	0.33	0	–	0	–	–	1	1	1	1	1	–	–	1	6/8	75
V-1a	0.33	0	–	1	–	–	1	1	1	1	1	–	–	1	7/8	88
12b	0.33	–	1	–	1	1	1	1	1	1	1	–	–	1	9/9	100
14b	0.33	–	1	–	1	1	1	1	1	1	–	1	1	1	10/10	100
30b	0.35	0	–	0	–	–	1	1	1	1	1	–	–	1	6/8	75
18b	0.35	1	–	1	–	–	0	1	1	1	–	1	1	1	8/9	89
6a	0.36	–	0	–	0	0	1	1	0	0	–	–	–	0	2/8	25
31a	0.36	1	–	1	–	–	0	1	1	1	–	1	1	0	7/9	78
6d	0.37	–	1	–	0	0	0	1	0	0	–	–	–	0	2/8	25
27b	0.37	1	–	1	–	–	0	1	1	1	–	1	1	0	7/9	78
28a	0.46	–	1	–	0	1	1	1	1	1	0	–	–	1	7/9	78
13a	0.58	1	–	1	–	–	1	1	1	1	–	1	1	1	9/9	100
8a	0.58	1	–	1	–	–	0	1	–	1	–	0	0	1	5/8	63
V-1b	0.60	0	–	1	–	–	1	1	1	1	1	–	–	1	7/8	88
11a	0.63	1	–	1	–	–	0	1	–	1	1	–	–	1	6/7	86
14a	0.65	–	1	–	1	1	0	1	1	1	–	1	1	1	9/10	90
12a	0.66	–	1	–	1	1	0	1	1	1	1	–	–	1	8/9	89
7a	0.72	–	1	–	0	1	0	1	1	1	0	–	–	1	6/8	75
7b	0.75	–	1	–	0	1	1	1	1	1	0	–	–	1	7/9	78
F		5	3	1	20	4	33	0	4	26	0	0	0	0		
Σ/N		14/32	11/20	19/31	10/20	15/20	21/52	39/52	35/40	39/52	10/18	15/25	15/25	32/52		
%		44	55	61	50	75	40	75	88	75	56	60	60	62		

FIGURE 5-5. RAW DATA SHEET - SAMPLE B, EDDY CURRENT SURFACE SPECIMENS OVERHEAD (Continued)

FLAW ID	FLAW SIZE	0203	0206	0209	03R1	03R3	03R5	03R7	03R9	03R11	03R13	03R15	0407	0405	0501	0502	0506	0507	0508
		TECHNICIAN ID																	
33b	.08	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
V-2a	0.10	0	1	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0
29b	0.10	0	0	—	1	1	0	1	0	0	0	0	—	0	0	0	0	0	0
42a	0.10	0	0	0	0	0	0	1	0	—	0	0	0	0	0	0	0	0	0
25a	0.11	1	1	1	0	—	0	0	0	0	0	0	0	0	0	0	0	0	0
6b	0.12	0	1	1	0	0	0	1	0	0	0	0	0	0	—	0	1	0	1
1a	0.12	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
2b	0.12	0	0	0	0	0	0	1	—	0	0	0	0	0	0	0	0	0	0
36b	0.13	0	0	0	1	1	0	1	0	0	0	1	0	0	0	0	1	1	0
40a	0.14	0	0	0	0	1	0	0	0	1	1	0	1	1	0	0	0	—	0
34b	0.15	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
U-1b	0.15	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29b	0.15	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
6c	0.15	0	1	1	0	0	0	1	0	0	0	0	0	0	—	0	1	0	0
4a	0.16	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
9b	0.17	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
31b	0.17	0	0	—	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0
U-1a	0.18	1	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0
35b	0.19	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	1	0	0
3a	0.20	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
5a	0.20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
27a	0.21	0	0	—	0	1	1	0	0	0	0	0	0	0	0	0	1	0	0
8b	0.23	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
26a	0.23	0	0	1	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0
3b	0.23	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0
25b	0.26	1	1	1	1	1	0	0	0	0	0	0	1	0	0	0	0	1	0
28b	0.27	0	1	0	1	1	0	0	0	1	1	0	1	0	1	0	1	1	0
9a	0.28	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	—	0	0
26b	0.29	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0
23a	0.30	0	—	0	0	0	1	0	—	0	1	0	0	0	0	0	0	0	0
33a	0.30	0	0	0	0	0	0	0	—	0	0	0	0	0	0	0	0	0	0
34a	0.31	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
11b	0.32	1	1	0	1	1	1	1	1	1	1	0	1	1	1	0	1	0	1
30a	0.33	1	1	1	1	1	1	1	0	0	1	0	1	1	1	0	1	1	0
V-1a	0.33	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1
12b	0.33	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1
14b	0.33	1	1	1	1	1	1	0	1	1	1	1	0	1	1	1	1	1	1
30b	0.35	1	1	1	1	1	1	1	0	0	1	0	1	1	1	0	1	1	0
18b	0.35	1	1	—	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1
6a	0.36	1	1	1	0	1	0	1	0	0	0	0	0	0	—	0	1	1	1
31a	0.36	1	0	—	0	1	1	0	0	0	0	0	0	1	1	0	0	0	0
6d	0.37	0	1	1	0	1	0	1	0	0	0	0	0	0	—	0	1	1	0
27b	0.37	0	0	—	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
28a	0.46	1	1	1	1	1	0	0	0	1	1	0	1	1	1	0	1	1	0
13a	0.58	1	1	—	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1
8a	0.58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
V-1b	0.60	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1
11a	0.63	1	1	0	1	1	1	1	1	1	1	0	1	1	1	0	1	0	1
14a	0.65	1	1	1	1	1	1	0	1	1	1	1	0	1	1	1	1	1	1
12a	0.66	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1
7[illegible]	0.7[illegible]	1	0	1	1	1	1	1	0	0	0	0	1	1	1	1	1	1	0
7b	0.75	1	1	1	1	1	1	1	0	0	0	0	1	1	1	1	1	1	0
F		5	0	0	20	35	29	39	98	9	63	3	7	1	25	32	20	15	9
Σ/N		21/52	22/51	20/45	20/52	28/52	18/52	26/52	9/49	13/51	16/52	7/52	20/51	22/52	18/40	8/52	23/51	20/51	12/52
%		40	43	44	38	54	35	52	18	25	31	13	39	42	36	15	45	39	23

FIGURE 5-6. RAW DATA SHEET - SAMPLE B, RADIOGRAPHIC NDI

		TECHNICIAN ID																	
FLAW ID	FLAW SIZE	0601	0606	0803	0806	0807	1001	1003	1014	1011	1025	1021	1026	1028	1104	1109	1111	1119	1124
33b	.08	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
V-2a	0.10	1	0	1	1	0	0	0	1	0	1	0	0	1	0	1	1	1	0
24b	0.10	0	0	–	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
42a	0.10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
25a	0.11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6b	0.12	1	0	1	1	0	0	0	1	1	0	0	0	0	0	0	1	1	1
1a	0.12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2b	0.12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	–	0
36b	0.13	1	0	1	0	0	0	1	1	1	0	0	0	0	1	0	0	1	1
40a	0.14	0	0	0	1	0	1	0	0	0	0	0	0	0	0	1	1	1	1
34b	0.15	0	0	–	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
U-1b	0.15	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
29b	0.15	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
6c	0.15	1	0	1	1	0	1	0	1	1	0	0	0	0	0	0	1	1	1
4a	0.16	0	–	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9b	0.17	0	0	–	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0
31b	0.17	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	1	1	1
U-1a	0.18	1	0	0	0	1	0	1	1	1	1	1	0	0	0	0	1	1	1
35b	0.19	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3a	0.20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5a	0.20	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27a	0.21	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1	0
8b	0.23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26a	0.23	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	1	1	0
3b	0.23	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25b	0.26	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1
28b	0.27	1	0	0	0	0	1	1	1	1	1	1	0	0	1	0	1	1	1
9a	0.28	0	–	–	1	1	0	0	0	1	0	0	1	0	0	0	1	0	0
26b	0.29	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	1	1	1
23a	0.30	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0
33a	0.30	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
34a	0.31	0	0	–	0	0	1	0	0	0	1	0	0	0	0	0	1	1	1
11b	0.32	1	1	1	0	1	1	0	1	1	1	0	1	1	1	1	1	1	1
30a	0.33	1	1	–	1	1	1	0	1	1	1	0	0	0	1	0	1	1	1
V-1a	0.33	1	1	1	1	1	1	0	1	1	1	0	1	1	1	1	1	1	1
1Eb	0.33	1	1	–	1	1	1	0	1	1	1	0	1	1	1	1	1	1	1
14b	0.33	1	1	1	1	1	1	0	1	1	1	0	1	1	1	1	1	1	1
30b	0.35	1	1	1	1	1	1	0	1	1	1	0	0	0	1	0	1	1	1
18b	0.35	1	1	1	1	1	1	0	1	1	1	0	1	1	1	1	0	1	1
6a	0.36	1	0	–	1	0	0	0	1	1	0	0	0	0	0	1	1	1	0
31a	0.36	0	0	1	0	1	0	1	0	1	0	0	0	0	0	0	1	1	1
6d	0.37	1	0	1	1	0	0	0	1	1	0	1	0	0	0	0	1	1	0
27b	0.37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
28a	0.46	1	1	0	0	1	1	1	1	1	1	1	0	0	1	0	1	1	1
13a	0.58	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1
8a	0.58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
V-1b	0.60	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
11a	0.63	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
14a	0.65	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
12a	0.66	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
7a	0.72	1	0	0	0	1	1	1	1	1	1	1	0	0	0	0	1	1	0
7b	0.75	1	0	0	0	0	1	1	1	1	1	1	0	0	0	0	1	1	1
F		47	6	36	24	20	36	7	10	14	0	3	0	12	0	1	2	0	0
S/N		24/52	14/50	19/44	19/52	18/52	21/52	12/52	25/52	26/52	22/52	22/52	12/52	11/52	15/52	13/52	31/52	34/52	26/52
%		46	28	43	37	35	40	23	48	50	42	42	23	21	29	25	60	65	50

FIGURE 5-6. RAW DATA SHEET - SAMPLE B, RADIOGRAPHIC NDI (Continued)

FLAW ID	FLAW SIZE	TECHNICIAN ID 1204	1302	1305	1325	1312	1315	1316	1317	1328	1359	1327	1403	1501	16R1	16R3	16R6	16R8
33b	.08	0	0	0	0	0	0	0	0	0	0	0	0	–	0	0	0	0
V-2a	0.10	0	1	0	0	0	1	1	0	0	0	1	1	–	0	1	1	1
29b	0.10	0	0	0	0	0	1	1	0	0	0	0	1	–	0	0	0	0
42a	0.10	0	0	0	0	0	0	0	0	0	0	0	0	–	0	0	0	0
25a	0.11	0	0	0	0	0	0	0	0	0	0	0	0	–	1	0	0	0
6b	0.12	1	1	0	1	0	1	1	0	0	0	0	1	–	0	0	1	0
1a	0.12	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
2b	0.12	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
36b	0.13	0	0	0	0	0	0	1	0	0	1	1	1	0	0	1	0	0
40a	0.14	1	0	1	1	0	0	0	0	0	1	0	0	0	1	0	1	0
34b	0.15	0	0	0	1	0	0	0	0	0	0	1	0	–	0	0	0	0
U-1b	0.15	0	0	0	0	0	0	0	0	0	1	0	0	–	1	1	0	0
29b	0.15	0	0	0	1	0	0	1	0	0	0	0	0	–	0	0	0	0
6c	0.15	1	1	0	1	0	1	1	0	0	0	0	1	–	0	0	0	0
4a	0.16	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
9b	0.17	0	1	0	0	0	0	0	0	0	0	0	0	–	0	0	1	1
31b	0.17	1	0	0	1	0	1	0	0	0	1	0	1	–	0	0	0	0
U-1a	0.18	0	0	0	0	0	1	0	0	0	1	0	1	–	1	1	0	0
35b	0.19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3a	0.20	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
5a	0.20	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
27a	0.21	0	0	0	0	0	0	0	0	0	0	0	1	–	0	0	0	0
8b	0.23	0	0	0	0	0	0	0	0	0	0	0	0	–	0	0	0	0
26a	0.23	1	0	0	0	0	0	0	0	0	0	1	1	–	0	0	0	0
3b	0.23	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
25b	0.26	0	0	0	0	0	1	0	0	0	0	0	1	–	1	0	0	0
28b	0.27	1	0	0	0	0	1	1	1	0	1	1	1	0	1	1	1	1
9a	0.28	0	1	0	0	0	0	0	0	0	0	0	0	–	0	0	1	1
26b	0.29	1	0	0	0	0	0	0	0	0	0	1	1	–	0	0	0	0
23a	0.30	0	0	0	0	0	0	0	0	0	0	0	1	–	0	0	0	0
33a	0.30	0	0	0	0	0	0	0	0	0	0	0	0	–	0	0	0	0
34a	0.31	0	0	0	1	0	1	0	0	0	1	1	1	–	0	0	0	0
11b	0.32	1	1	1	1	1	1	1	1	1	1	1	1	–	1	1	1	1
30a	0.33	1	1	1	1	0	1	1	0	1	1	1	1	–	1	1	1	1
V-1a	0.33	1	1	1	1	1	1	1	1	1	1	1	1	–	1	1	1	1
12b	0.33	1	1	1	1	0	1	1	1	1	1	1	1	–	1	1	1	1
14b	0.33	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
30b	0.35	1	1	1	1	0	1	1	0	1	1	1	1	–	1	1	1	1
13b	0.35	1	1	1	1	1	1	1	1	1	1	1	1	–	1	1	1	1
6a	0.36	1	1	0	1	0	1	1	0	0	1	0	1	–	0	0	1	1
31a	0.36	1	0	0	1	0	1	0	0	0	1	0	1	–	0	0	0	0
6d	0.37	1	1	0	1	0	1	1	0	0	1	0	1	–	0	0	0	1
27b	0.37	0	0	0	0	0	0	0	0	0	0	0	1	–	0	0	0	0
28a	0.46	1	0	0	1	0	1	1	1	0	1	1	1	0	1	1	1	1
13a	0.58	1	1	1	1	1	1	1	1	1	1	1	1	–	1	1	1	1
8a	0.58	0	0	0	0	0	0	0	0	1	0	0	0	–	0	1	0	0
V-1b	0.60	1	1	1	1	1	1	1	1	1	1	1	1	–	1	1	1	1
11a	0.63	1	1	1	1	1	1	1	1	1	1	1	1	–	1	1	1	1
14a	0.65	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1
12a	0.66	1	1	1	1	0	1	1	1	1	1	1	1	–	1	1	1	1
7a	0.72	1	0	0	1	0	1	1	0	0	1	1	1	–	1	1	1	1
7b	0.75	1	0	0	1	0	1	1	0	0	1	1	1	–	1	1	1	1
F		7	9	3	23	16	15	37	16	1	13	9	27	0	2	8	17	3
Σ/N		25/52	19/46	13/46	25/46	8/46	27/46	24/46	12/46	13/46	25/46	22/46	33/46	1/7	21/46	21/46	22/46	21/46
%		48	41	28	54	17	59	52	26	28	54	48	72	14	46	46	48	46

FIGURE 5-6. RAW DATA SHEET - SAMPLE B, RADIOGRAPHIC NDI (Continued)

FLAW ID	FLAW SIZE	TECHNICIAN ID 17R0	18R1	18R3	18R6	2004	2008	2014	Σ/N	%
33b	.08	0	0	0	0	0	0	0	1/59	1.7
V-2a	0.10	0	0	0	0	0	0	0	21/59	35.6
29b	0.10	1	0	0	0	0	0	0	8/56	14.3
42a	0.10	0	0	0	0	0	0	0	2/58	3.4
25a	0.11	0	0	0	0	0	0	1	5/58	8.6
6b	0.12	0	0	0	0	0	0	0	20/58	34.5
1a	0.12	–	–	–	–	–	–	–	0/37	0
2b	0.12	–	–	–	–	–	–	–	1/35	2.9
36b	0.13	1	0	0	0	0	0	0	20/60	33.3
40a	0.14	0	0	0	0	0	1	0	18/59	30.5
34b	0.15	0	0	0	0	0	0	0	5/58	8.6
U-1b	0.15	0	0	0	0	0	0	1	6/56	10.7
29b	0.15	0	0	0	0	0	0	0	5/59	8.5
6c	0.15	0	0	0	0	0	0	0	19/58	32.8
4a	0.16	–	–	–	–	–	–	–	1/36	2.8
9b	0.17	1	0	0	0	0	0	0	7/58	12.1
31b	0.17	1	0	0	0	0	0	0	13/58	22.4
U-1a	0.18	1	0	0	0	0	0	1	21/58	36.2
35b	0.19	1	0	0	0	0	0	1	6/60	10.0
3a	0.20	–	–	–	–	–	–	–	1/37	2.7
5a	0.20	–	–	–	–	–	–	–	2/37	5.4
27a	0.21	1	0	0	0	0	0	0	8/58	13.8
8b	0.23	0	0	0	0	0	0	0	1/59	1.7
26a	0.23	1	0	0	0	0	0	0	13/59	22.0
3b	0.23	–	–	–	–	–	–	–	3/37	8.1
25b	0.26	1	0	0	0	0	0	1	16/59	27.1
28b	0.27	1	0	0	0	0	1	0	33/60	55.0
9a	0.28	1	0	0	0	0	0	0	11/56	19.6
26b	0.29	1	0	0	0	0	0	0	12/59	20.3
23a	0.30	0	0	0	0	0	0	0	5/57	8.8
33a	0.30	0	0	0	0	0	0	0	4/57	7.0
34a	0.31	1	0	0	0	0	0	0	11/57	19.3
11b	0.32	1	0	1	0	1	0	1	49/59	83.1
30a	0.33	1	0	0	0	1	0	0	41/58	70.7
V-1a	0.33	1	0	1	1	1	0	1	54/59	91.5
12b	0.33	1	1	1	0	1	0	1	52/58	89.7
14b	0.33	1	0	1	0	1	0	1	53/60	88.3
30b	0.35	1	0	0	0	1	0	0	42/59	71.2
18b	0.35	1	0	1	1	1	0	1	52/58	89.7
6a	0.36	1	0	0	0	0	0	0	25/57	43.9
31a	0.36	1	0	0	0	0	0	0	17/58	29.3
6d	0.37	1	0	0	0	0	0	0	23/58	39.7
27b	0.37	1	0	0	0	0	0	0	15/58	25.9
28a	0.46	1	0	0	0	0	1	0	20/60	33.3
13a	0.58	1	0	1	1	1	0	1	53/58	91.4
8a	0.58	0	0	0	0	0	0	0	2/59	3.4
V-1b	0.60	1	0	1	1	1	0	1	55/58	94.8
11a	0.63	1	1	1	0	1	0	1	51/59	86.4
14a	0.65	1	0	1	0	1	0	1	54/60	90.0
12a	0.66	1	1	1	0	1	0	1	54/59	91.5
7a	0.72	1	0	0	0	0	1	0	35/59	59.3
7b	0.75	1	0	0	0	0	1	0	36/59	61.0
F		–	16	13	20	28	4	6		
Σ/N		32/46	3/46	10/46	4/46	12/46	5/46	14/46		
%		70	7	22	9	26	11	30		

FIGURE 5-6. RAW DATA SHEET - SAMPLE B, RADIOGRAPHIC NDI (Continued)

		TECHNICIAN ID																		
Flaw ID	Flaw Size	0201	0202	0204	0205	0208	0341	0342	0343	0403	0406	0502	0504	0605	0901	0903	0910	0911	1017	1034
44A	.02	1	1	1	0	1	1	1	1	-		1	0	0	1	-	1	-	1	1
44B	.06	1	1	1	0	1	1	1	1	0	1	0	0	0	1	-	1	-	1	1
39A	.06	1	-	0	1	0	1	1	1	-	-	0	0	0	0	-	0	-	0	0
40A	.06	-	-	1	1	0	0	0	0	-	-	0	0	0	1	1	0	0	1	0
15A	.06	1	-	-	1	0	0	1	1	-	-	0	0	0	1	1	0	1	1	1
15B	.06	1	-	-	1	0	0	1	1	0	1	1	0	0	1	1	0	1	1	1
40B	.07	-	-	1	1	0	0	0	0	-	1	0	0	0	1	1	0	0	1	0
43B	.08	1	-	1	1	1	0	0	0	1	0	1	0	0	1	-	1	-	1	1
43A	.09	1	-	1	1	0	0	0	0	-	-	1	0	0	1	-	0	-	1	1
37A	.09	1	1	1	1	1	1	1	1	-	-	1	0	0	1	-	1	-	1	1
37B	.10	1	1	1	0	0	1	1	0	1	0	1	0	0	1	-	1	-	1	1
14B	.10	1	-	1	1	0	1	1	1	1	1	1	0	0	1	-	1	-	1	1
14A	.11	1	-	1	0	1	1	1	1	-	-	1	0	0	1	-	1	-	1	1
51B	.12	1	1	1	1	1	0	1	1	1	1	1	1	0	1	-	0	-	1	1
34A	.14	-	-	-	0	1	0	1	1	-	-	0	0	0	1	1	0	0	1	1
34B	.14	-	-	-	0	1	0	1	1	0	1	0	0	0	1	1	0	0	0	1
54B	.14	-	-	1	0	1	0	0	1	0	1	0	1	0	1	1	1	0	1	0
51A	.15	1	1	1	1	1	0	1	1	-	-	1	1	0	1	-	0	-	1	1
54A	.17	-	-	1	1	1	1	0	1	-	-	0	1	0	1	1	1	1	1	0
41A	.17	-	-	1	0	0	0	1	1	-	-	1	1	0	1	1	0	0	1	1
41B	.17	-	-	1	1	0	0	1	0	0	1	1	1	0	1	1	0	0	1	1
58A	.18	1	-	1	-	-	0	0	1	-	1	1	1	0	1	-	0	-	0	1
58B	.18	1	-	1	-	-	0	0	1	0	-	1	1	0	1	-	0	-	0	1
47A	.19	1	-	1	1	1	0	1	1	-	-	1	1	0	1	-	0	-	1	1
47B	.19	1	-	1	1	0	0	1	1	1	1	1	1	0	1	-	1	-	1	1
59A	.20	-	0	1	1	1	1	1	1	-	-	1	1	0	1	0	1	0	1	1
59B	.21	-	0	1	0	1	1	1	1	1	1	1	1	0	1	0	1	0	1	1
55A	.21	-	-	1	0	1	0	0	1	-	-	1	0	0	1	0	0	0	1	1
55B	.21	-	-	1	0	1	0	0	1	1	1	1	0	0	1	0	0	0	1	1
50A	.21	-	-	1	1	0	1	1	1	-	1	0	1	0	1	0	0	0	1	1
52A	.22	1	1	1	1	0	1	0	1	-	-	1	1	0	1	-	0	-	0	1
52B	.22	1	1	1	1	1	1	0	1	0	1	1	1	0	1	-	0	-	0	1
29B	.22	-	-	1	0	0	0	1	1	0	1	1	1	0	1	1	0	1	1	1
50B	.22	-	-	-	0	1	1	1	1	0	-	0	1	0	1	0	0	0	1	1
29A	.24	-	-	1	0	0	0	1	1	-	-	1	1	0	1	1	0	1	1	1
57A	.25	-	-	1	1	1	1	0	1	-	-	1	0	0	1	0	0	0	1	1
57B	.25	-	-	1	1	1	1	0	1	1	1	1	0	0	0	0	0	0	1	1
60B	.27	-	1	1	0	1	0	0	0	-	1	1	1	0	1	0	0	0	1	1
60A	.28	-	0	1	0	1	0	1	1	-	-	1	1	0	1	0	0	0	1	1
2B	.40	-	-	-	0	1	1	0	0	1	1	1	1	0	1	1	0	0	1	1
2A	.50	1	-	-	0	1	1	0	1	0	-	1	1	0	1	0	0	0	1	1
F		0	16	2	14	2	129	7	94	7	4	19	12	10	6	3	24	62	12	5
Σ/N		20/20	9/12	33/34	21/39	24/39	18/41	24/41	33/41	9/19	18/20	30/41	22/41	0/41	39/41	13/24	12/41	5/24	35/41	36/41
%		100	75	97	54	62	44	59	80	47	90	73	54	0	95	54	29	21	85	88

FIGURE 5-7. RAW DATA SHEET - SAMPLE C, ULTRASONIC SHEAR WAVE SCANS

		TECHNICIAN ID																	
Flaw ID	Flaw Size	1107	1113	1115	1203	1303	1305	1310	1312	1314	1323	1332	6E24	1701	1801	1802	1808	Σ/N	%
44A	.02	0	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	25/32	78.1
44B	.06	0	1	1	-	-	-	-	-	1	-	-	-	-	0	-	-	15/22	68.2
39A	.06	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	9/31	29.0
40A	.06	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	20/32	62.5
15A	.06	1	1	1	1	1	1	0	1	0	1	1	0	1	1	1	1	22/32	68.8
15B	.06	1	1	1	-	-	-	-	-	0	-	-	-	-	0	-	-	14/22	63.6
40B	.07	1	1	1	-	-	-	-	-	1	-	-	-	-	0	-	-	10/21	47.6
43B	.08	1	1	1	-	-	-	-	-	1	-	-	-	-	0	-	-	14/21	66.7
43A	.09	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	22/30	73.3
37A	.09	1	1	0	0	1	1	1	0	1	1	0	0	1	1	1	1	24/31	77.4
37B	.10	1	1	0	-	-	-	-	-	1	-	-	-	1	0	-	-	15/23	65.2
14B	.10	1	1	1	-			-	-	1	-	-	-	-	0	-	-	16/21	76.2
14A	.11	1	1	1	0	1	1	1	1	1	1	0	1	0	1	1	1	24/29	82.8
51B	.12	1	1	1	-	-	-		-	1	-	-	-	-	0	-	-	15/22	81.8
34A	.14	1	1	1	1	1	1	1	1	1	1	0	0	1	0	1	1	20/30	66.7
34B	.14	1	1	1		-	-			1	-		-	-	0	-	-	11/21	52.4
54B	.14	1	1	1	-	-	-	-	-	1	-	-	-	-	0	-	-	13/22	59.1
51A	.15	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	28/31	90.3
54A	.17	1	1	1	1	1	1	1	1	1	1	0	0	1	0	1	1	24/31	77.4
41A	.17	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	24/31	77.4
41B	.17	1	1	1	-	-	-	-	-	1	-	-	-	-	0	-	-	14/22	63.6
58A	.18	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	24/29	82.8
58B	.18	1	1	1	-	-	-	-	-	1	-	-	-	-	0	-	-	11/18	61.1
47A	.19	1	1	1	1	1	1	1	1	1	-	1	1	1	0	0	1	24/29	8[illegible].8
47B	.19	1	1	1	-	-	-	-	-	1	-	-	-	-	0	-	-	17/21	81.0
59A	.20	1	1	1	1	0	1	1	1	1	1	0	1	1	1	1	1	26/32	81.3
59B	.21	1	1	1	1	-	-	-	-	1	-	-	-	-	0	-	-	18/24	75.0
55A	.21	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	21/31	67.7
55B	.21	1	1	1	-	-	-	-	-	1	-	-	-	-	0	-	-	13/22	59.1
50A	.21	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	1	24/31	77.4
52A	.22	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	26/33	78.8
52B	.22	1	1	1	-	-	-	-	-	1	-	-	-	-	0	-	-	16/23	69.6
29B	.22	1	1	0	-	-	-	-	-	1	-	-	-	-	0	-	-	14/23	60.9
50B	.22	1	1	1	-	-	-	-	-	1	-	-	-	-	0	-	-	12/20	60.0
29A	.24	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	25/31	80.6
57A	.25	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	25/31	80.6
57B	.25	1	1	1	1	-	-	-	-	1	-	-	-	-	0	-	-	15/18	83.3
60B	.27	1	1	1	1	-	-	-	-	1	-	-	-	-	0	-	-	14/23	60.9
60A	.28	1	1	1	1	1	1	1	1	1	1	0	1	-	0	0	1	21/31	67.7
2B	.40	1	1	1	-	-	-	-	-	1	-	-	-	-	0	-	-	14/21	66.7
2A	.50	1	1	1	-	1	1	1	1	1	1	1	1	1	1	1	1	24/31	77.4
F		4	4	10	[illegible]	1	9	1	0	1	0	2	0	14	16	46	0		
Σ/N		38/41	37/41	36/41	20/23	18/21	18/21	19/21	19/21	38/41	18/20	11/21	15/21	20/21	16/41	19/21	21/21		
%		93	90	88	87	85.7	85.7	90.5	91	93	90	52	71	95	39	91	100		

FIGURE 5-7. RAW DATA SHEET - SAMPLE C, ULTRASONIC SHEAR WAVE SCANS (Continued)

		TECHNICIAN ID																				
Flaw ID	Flaw Size	0202	0203	0206	0209	03P1	03P2	03P3	03P4	03P5	03P6	03P7	03P8	03P9	0401	0402	0405	0407	C502	0504	0506	0507
44A	.02	0	0	1	0	1	0	0	-	0	-	0	0	0	0	-	0	0	0	0	0	1
44B	.06	0	0	1	0	1	1	0	-	0	-	0	1	0	0	-	0	1	1	1	0	0
39A	.06	-	0	0	0	-	0	0	-	0	-	0	0	0	0	-	0	1	0	0	0	0
40A	.06	-	1	1	1	-	1	1	-	0	1	0	0	0	1	-	0	1	0	1	0	0
15A	.06	-	1	0	1	-	1	0	-	0	0	0	1	0	0	-	0	0	0	1	0	1
15B	.06	-	1	1	0	-	1	0	-	0	1	0	0	0	0	-	0	0	0	1	0	0
40B	.07	-	1	1	1	-	1	1	-	0	1	0	0	0	1	-	0	1	0	1	0	0
43B	.08	-	1	1	0	-	0	0	-	0	-	0	0	1	1	0	0	1	1	1	0	1
43A	.09	-	1	1	0	-	0	0	-	0	-	0	0	0	1	0	0	1	1	1	0	0
37A	.09	1	1	1	1	1	1	0	-	1	-	0	1	1	1	-	1	1	1	1	1	1
37B	.10	1	1	1	1	1	1	0	-	1	-	0	1	1	1	-	1	1	1	1	1	1
14B	.10	1	0	1	0	1	1	1	-	0	-	0	1	0	1	-	1	1	1	1	0	1
14A	.11	0	1	1	0	1	1	1	-	0	-	0	1	0	1	-	1	1	1	1	1	0
51B	.12	1	1	1	1	-	1	1	-	1	-	0	1	1	1	-	1	1	1	1	0	1
34A	.14	1	-	1	-	-	1	1	-	1	1	1	1	1	1	0	1	1	0	1	1	0
34B	.14	1	1	1	1	-	1	1	-	1	1	0	1	1	1	0	0	1	1	1	1	0
54B	.14	1	1	1	1	-	1	1	0	1	1	0	1	1	1	0	0	1	1	1	1	1
51A	.15	1	1	1	1	-	1	1	-	1	-	0	1	1	1	-	1	1	1	1	0	1
54A	.17	1	1	1	1	-	1	1	0	1	1	1	1	1	1	0	1	1	1	1	1	0
41A	.17	-	1	1	1	-	1	1	1	0	1	1	1	0	1	-	1	1	1	1	0	0
41B	.17	-	1	1	1	-	1	1	0	0	1	1	1	0	1	-	1	1	1	1	0	0
58A	.18	1	-	-	0	-	1	1	-	1	1	1	1	1	1	1	1	1	1	1	0	0
58B	.18	1	-	-	0	-	1	1	-	1	1	0	1	1	1	1	1	1	1	1	1	0
47A	.19	1	1	1	1	1	1	1	-	1	-	-	1	1	1	1	1	1	1	1	1	1
47B	.19	1	1	1	1	1	1	1	-	1	-	-	1	1	1	1	1	1	1	1	1	1
59A	.20	1	1	1	1	-	1	1	-	1	1	1	1	1	1	1	1	1	1	1	1	1
59B	.21	1	1	1	1	-	1	1	-	1	1	0	1	1	1	1	0	1	1	1	1	0
55A	.21	1	1	1	1	-	.	1	-	1	1	1	1	1	1	1	1	1	1	1	1	1
55B	.21	1	1	1	1	-	1	1	-	1	1	1	1	1	1	0	1	1	1	1	1	1
50A	.21	1	1	1	1	-	1	1	0	1	1	1	1	1	1	1	1	1	0	1	0	0
52A	.22	1	1	1	1	-	1	0	-	1	1	0	1	1	1	0	1	1	1	1	1	1
52B	.22	-	1	1	1	-	1	0	-	1	1	0	1	1	1	0	1	1	1	1	1	0
29B	.22	-	1	1	1	-	1	1	-	0	0	0	1	0	1	-	1	1	0	1	1	0
50B	.22	-	1	1	1	-	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1
29A	.24	-	1	1	1	-	1	1	-	1	1	0	1	0	1	-	1	1	0	1	1	1
57A	.25	-	1	1	0	-	0	0	-	0	0	0	0	0	0	-	1	0	1	1	0	0
57B	.25	-	1	1	0	-	0	0	-	0	0	0	0	0	0	-	1	0	1	1	0	0
60B	.27	-	1	1	1	-	1	1	-	1	1	1	1	1	1	0	1	1	1	1	1	1
60A	.28	-	1	1	1	-	1	1	-	1	1	1	1	1	1	1	1	1	1	1	1	1
2B	.40	-	1	1	1	-	1	1	-	1	1	0	1	0	1	-	1	1	1	1	0	1
2A	.50	-	1	1	1	-	1	1	-	1	1	1	1	0	1	-	1	1	1	1	0	1
F		2	0	0	0	6	0	6	6	41	16	48	4[illegible]	0	1	15	0	0	9	2	5	5
Σ/N		19/22	34/38	37/39	28/40	8/8	35/41	28/41	1/6	25/41	24/28	13/39	32/41	23/41	34/41	10/20	29/41	36/41	31/41	39/41	21/41	21/41
%		86	89	95	70	100	85	68	17	61	86	33	78	56	83	50	71	88	76	95	51	51

FIGURE 5-8. RAW DATA SHEET - SAMPLE C, PENETRANT NDI

		TECHNICIAN ID																
Flaw ID	Flaw Size	0601	0602	0605	0606	0701	0702	0703	0705	0801	0803	0806	0807	0901	0903	0906	0912	1014
44A	.02	-	-	-	0	0	0	0	0	0	-	1	0	0	0	0	0	0
44B	.06	-	-	-	0	0	0	0	0	0	-	1	0	0	0	0	0	1
39A	.06	-	-	-	0	0	0	0	0	-	-	0	1	0	0	0	0	0
40A	.06	-	1	-	0	0	0	1	1	-	1	0	0	0	0	0	0	0
15A	.06	1	-	0	1	1	0	0	1	-	1	0	0	0	0	0	0	0
15B	.06	1	-	0	1	1	0	0	1	-	1	0	0	0	0	0	0	0
40B	.07	-	1	-	0	0	0	1	1	-	1	0	0	0	0	0	0	0
43B	.08	-	-	-	0	0	0	0	1	1	-	1	1	0	0	0	0	0
49A	.09	-	-	-	0	0	0	0	1	1	-	1	1	0	0	0	0	1
37A	.09	-	-	-	1	1	0	1	1	-	-	1	1	1	0	1	1	1
37B	.10	-	-	-	1	0	1	0	1	-	-	1	1	1	0	1	1	1
14B	.10	-	-	-	0	1	0	1	1	-	-	1	1	0	0	0	1	0
14A	.11	-	-	-	0	0	0	0	1	-	-	1	1	0	0	0	1	0
51B	.12	-	-	-	1	0	0	1	1	1	-	1	1	1	0	1	1	1
34A	.14	1	-	-	1	0	1	0	1	-	1	1	1	1	0	1	1	1
34B	.14	1	-	-	1	0	0	0	1	-	1	1	1	1	0	1	1	0
54B	.14	-	1	-	-	0	1	1	1	-	1	1	1	1	0	1	1	0
51A	.15	-	-	-	1	0	0	1	1	1	-	1	1	1	0	1	1	1
54A	.17	-	1	-	-	1	1	1	1	-	1	1	1	1	0	1	1	1
41A	.17	-	1	-	1	0	0	0	1	-	1	1	1	0	0	0	1	0
41B	.17	-	1	-	1	0	0	0	1	-	1	1	1	0	0	0	1	0
58A	.18	-	-	-	1	0	0	1	1	1	-	1	0	1	0	1	1	1
58B	.18	-	-	-	1	1	1	0	1	1	-	1	0	1	0	1	1	0
47A	.19	-	-	-	1	1	1	1	1	1	-	0	1	1	0	0	1	1
47B	.19	-	-	-	1	1	1	1	1	1	-	0	1	1	0	0	1	1
59A	.20	-	1	-	1	0	1	1	1	1	-	1	1	1	0	0	1	1
59B	.21	-	1	-	1	0	0	1	1	1	-	1	1	1	0	0	1	1
55A	.21	-	1	-	1	0	1	1	1	1	-	1	1	1	0	1	1	0
55B	.21	-	1	-	1	0	1	1	1	1	-	1	1	1	0	1	1	0
50A	.21	-	1	-	1	0	1	1	1	-	1	1	1	1	0	1	1	1
52A	.22	-	1	-	1	0	0	0	1	1	-	1	1	1	0	0	1	0
52B	.22	-	-	-	1	0	0	0	1	1	-	1	1	1	0	0	1	0
29B	.22	1	-	-	1	0	0	0	0	-	1	0	1	0	0	0	1	0
50B	.22	-	-	-	1	0	1	1	1	-	1	1	1	1	0	1	1	1
29A	.24	1	-	-	1	0	0	0	1	-	1	0	1	0	0	0	1	0
57A	.25	-	0	-	1	0	0	0	1	0	-	0	1	0	0	0	1	1
57B	.25	-	0	-	1	0	0	0	1	0	-	0	1	0	0	0	1	1
60B	.27	-	1	-	1	0	0	1	1	1	-	1	1	1	0	1	1	1
60A	.28	-	1	-	1	0	1	1	1	1	-	1	1	1	0	1	1	1
2B	.40	1	-	0	1	0	0	1	1	-	1	1	1	0	1	0	1	1
2A	.50	1	-	0	1	0	0	1	1	-	1	1	1	0	0	0	1	1
F		1	0	0	13	0	0	5	0	2	2	0	2	2	0	0	0	3
Σ/N		8/8	14/16	0/4	30/39	8/41	13/41	21/41	37/41	16/20	16/16	30/41	33/41	22/41	1/41	16/41	32/41	21/41
%		100	88	0	77	20	32	51	90	80	100	73	80	54	2	39	78	51

FIGURE 5-8. RAW DATA SHEET - SAMPLE C, PENETRANT NDI (Continued)

		TECHNICIAN ID																				
Flaw ID	Flaw Size	1101	1102	1105	1106	1108	1111	1113	1114	1116	1126	1127	1318	1403	16P1E	16P2	16P3	16P4	16P5	16P6	16P7	16P8
44A	.02	0	0	0	-	0	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0
44B	.06	0	1	0	-	0	1	1	0	1	0	0	0	0	0	0	0	0	0	1	0	0
39A	.06	0	1	0	-	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
40A	.06	0	1	0	-	0	1	1	0	0	1	0	0	1	1	1	1	0	1	1	1	1
15A	.06	0	1	1	-	0	1	1	0	1	0	0	0	1	0	0	0	0	1	1	0	1
15B	.06	0	1	1	-	1	1	1	0	1	0	0	1	1	0	0	0	0	1	1	1	1
40B	.07	0	1	0	-	0	1	1	0	0	0	0	0	0	1	1	1	0	1	1	1	1
43B	.08	0	1	1	-	1	1	0	0	1	1	0	0	0	0	1	0	0	1	1	1	0
43A	.09	1	1	1	-	1	1	0	1	1	1	0	0	0	0	1	0	0	1	1	1	0
37A	.09	1	1	1	-	1	1	1	1	1	1	0	1	1	0	1	1	1	1	1	1	1
37B	.10	1	1	1	-	1	1	1	1	1	1	1	0	0	0	1	0	1	1	1	1	1
14B	.10	0	1	1	-	1	1	1	0	1	1	1	0	0	0	1	0	1	1	0	1	1
14A	.11	0	1	1	-	1	1	1	0	1	1	0	0	0	0	1	1	1	1	0	1	1
51B	.12	1	1	1	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
34A	.14	1	1	1	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
34B	.14	1	1	1	-	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1
54B	.14	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
51A	.15	1	1	1	-	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1
54A	.17	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
41A	.17	1	1	1	-	1	1	1	0	1	1	0	0	0	1	1	1	1	1	1	1	1
41B	.17	1	1	1	-	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1
58A	.18	1	1	1	-	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1
58B	.18	1	1	1	-	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1
47A	.19	1	1	1	-	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1
47B	.19	1	0	1	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
59A	.20	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1
59B	.21	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1	1	1	1	1	1
55A	.21	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1
55B	.21	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
50A	.21	1	1	1	-	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1
52A	.22	1	1	1	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
52B	.22	1	1	1	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
29B	.22	1	1	1	-	1	1	1	0	1	0	1	0	1	1	1	1	1	1	1	1	1
50B	.22	1	1	1	-	1	1	1	1	1	0	1	1	1	1	1	0	1	1	1	1	1
29A	.24	1	1	1	-	1	1	1	0	1	0	1	0	1	1	1	1	1	1	1	1	1
57A	.25	1	1	0	0	0	1	1	1	1	1	0	0	0	0	1	0	0	1	0	1	0
57B	.25	0	1	0	0	0	1	1	0	1	0	0	0	0	0	1	0	0	1	0	1	0
60B	.27	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
60A	.28	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2B	.40	1	1	1	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2A	.50	1	1	1	-	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1
F		0	0	2	0	0	0	3	99	1	7	5	2	6	1	0	5	0	1	1	0	1
Σ/N		30/41	39/41	34/41	8/10	33/41	41/41	38/41	25/41	38/41	30/41	20/41	24/41	28/41	28/41	36/41	29/41	30/41	38/41	36/41	37/41	34/41
%		73	95	83	80	80	100	93	61	93	73	49	59	68	68	88	71	73	93	88	90	83

FIGURE 5-8. RAW DATA SHEET - SAMPLE C, PENETRANT NDI (Continued)

		TECHNICIAN ID										
Flaw ID	Flaw Size	1808	1814	1817	1821	1823	2001	2004/2	2008/2	2206	Σ/n	%
44A	.02	1	0	0	0	1	0	0	0	0	9/60	15.0
44B	.06	1	0	0	1	1	1	0	1	0	18/60	30.0
39A	.06	1	0	0	0	0	1	0	0	0	6/57	10.5
40A	.06	1	0	0	1	1	1	1	0	1	31/59	52.5
15A	.06	1	0	0	0	1	1	0	0	0	23/61	37.7
15B	.06	1	0	0	1	1	1	0	0	1	27/61	44.3
40B	.07	1	0	1	0	1	1	1	1	1	30/60	50.0
43B	.08	1	0	0	1	0	1	0	0	0	25/61	41.0
43A	.09	1	0	0	1	0	1	0	0	0	26/59	44.1
37A	.09	–	1	1	1	1	1	1	0	1	51/58	87.9
37B	.10	–	1	1	1	1	1	1	0	1	48/58	82.8
14B	.10	–	1	0	1	1	1	1	0	1	37/58	63.8
14A	.11	–	1	0	0	1	1	1	0	1	36/58	62.1
51B	.12	1	1	1	1	1	1	1	1	1	54/59	91.5
34A	.14	1	1	1	1	1	1	1	1	1	54/60	90.0
34B	.14	1	1	0	1	1	1	1	0	1	50/62	80.6
54B	.14	1	1	0	1	1	1	1	0	1	54/63	85.7
51A	.15	1	1	1	1	1	1	1	0	1	52/59	88.1
54A	.17	1	1	0	1	1	1	1	0	1	57/63	90.5
41A	.17	1	1	0	1	1	1	1	1	1	45/61	73.8
41B	.17	1	1	0	1	1	1	1	1	1	47/60	78.3
58A	.18	1	1	1	1	1	1	1	0	1	50/59	84.7
58B	.18	1	1	1	1	1	1	1	0	1	50/59	84.7
47A	.19	1	1	1	0	1	1	1	1	1	55/60	91.7
47B	.19	1	1	1	1	1	1	1	1	1	56/60	93.3
59A	.20	1	1	1	1	1	1	–	0	1	56/60	93.3
59B	.21	1	1	1	0	1	1	–	0	1	50/61	82.0
55A	.21	1	1	1	1	1	1	1	1	1	58/62	93.5
55B	.21	1	1	1	1	1	1	1	0	1	57/63	90.5
50A	.21	1	1	1	0	1	1	1	1	1	55/63	87.3
52A	.22	1	1	1	1	1	1	1	1	1	53/63	85.5
52B	.22	1	1	1	1	1	1	1	1	1	49/60	81.7
29B	.22	1	1	0	1	1	1	1	0	1	40/59	67.8
50B	.22	1	1	0	1	1	1	1	1	0	54/60	90.0
29A	.24	1	1	0	0	1	1	1	0	1	43/59	72.9
57A	.25	1	0	0	0	0	1	0	0	0	22/61	36.1
57B	.25	1	0	1	0	0	0	0	0	0	19/61	31.1
60B	.27	1	1	1	1	1	1	1	0	1	57/63	91.9
60A	.28	1	1	1	1	1	1	1	1	1	60/62	96.8
2B	.40	1	1	1	1	1	1	1	1	1	53/61	86.9
2A	.50	1	1	1	0	1	1	1	0	1	50/61	82.0
F		2	0	16	35	1	0	6	1	0		
Σ/N		37/37	30/41	22/41	29/41	36/41	39/41	30/39	15/41	32/41		
%		100	73	54	71	88	95	73	37	78		

FIGURE 5-8. RAW DATA SHEET - SAMPLE C, PENETRANT NDI (Continued)

Flaw ID	Flaw Size	0202	0204	0205	0206	0208	0209	0341	0342	0343	0402	0405	0501	0502	0505	0605	0705	0901	0908	0909	0915
D2-10	<.02	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0
D2-5	<.02	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
D2-12	.02	0	0	1	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0
D1-24	.03	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	—
D1-8	.03	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	—
D1-48	.03	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1	—
D1-69	.03	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	—
D1-34	.04	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	—
D1-68	.04	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	—
D2-3	.04	0	0	1	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0
F		0	20	20	0	0	1	17	15	0	34	2	0	0	1	0	0	1	25	35	0
Σ/N		0/10	2/10	3/10	0/10	0/10	0/10	3/10	3/10	0/10	4/10	0/10	0/10	0/10	0/10	0/10	0/10	0/10	2/10	5/10	0/4
%		0	20	30	0	0	0	30	30	0	40	0	0	0	0	0	0	0	20	50	0

FIGURE 5-9. RAW DATA SHEET - SAMPLE D, ULTRASONIC SHEAR WAVE SCANS

Flaw ID	Flaw Size	1006	1012	1017	1034	1106	1107	1118	1207	1302	1303	1310	1311	1313	1318	1319	1322	1323	1385	1308	1403	16E3U	1642	1644
		TECHNICIAN ID																						
* D2-10	<.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0
* D2-5	<.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0
* D2-12	.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0
* D1-24	.03	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	–	0	0	0	–	0	1	0
* D1-8	.03	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	–	0	0	1	–	1	0	0
* D1-48	.03	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	–	0	0	1	–	0	0	0
* D1-69	.03	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	–	0	0	0	–	1	0	0
* D1-34	.04	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	–	0	0	1	–	0	0	0
* D1-68	.04	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	–	0	0	0	–	0	0	0
* D2-3	.04	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	0	0	1	0	0	0
F		3	0	0	0	0	0	0	0	1	0	4	2	2	5	30	1	0	1	45	9	11	8	0
Σ/N		0/10	0/10	0/10	0/10	0/10	0/10	0/10	0/10	0/10	0/10	0/10	0/10	2/10	0/10	3/10	1/4	0/10	0/10	6/10	3/4	2/10	1/10	0/10
%		0	0	0	0	0	0	0	0	0	0	0	0	20	0	30	25	0	0	60	75	20	10	0

FIGURE 5-9. RAW DATA SHEET - SAMPLE D, ULTRASONIC SHEAR WAVE SCANS (Continued)

Flaw ID	Flaw Size	TECHNICIAN ID 1645	1638	1631		1202	1216	1218																	Σ/N	%
* D2-10	<.02	0	0			0	0	0																	5/49	10.2
* D2-5	<.02	0	0			0	0	0																	4/49	8.2
* D2-12	.02	0	0			1	1	0																	7/49	14.3
* D1-24	.03	0	0			0	0	0																	2/45	4.4
* D1-8	.03	0	0			0	0	0																	4/46	8.7
* D1-48	.03	0	0			0	0	0																	6/46	13.0
* D1-69	.03	0	0			0	0	0																	3/46	6.5
* D1-34	.04	0	0			0	0	0																	5/46	10.9
* D1-68	.04	0	0			0	0	0																	0/46	0
* D2-3	.04	0	0			0	1	0																	7/46	15.2
F		0	0			2	65	5																		
Σ/N		0/10	0/10			1/10	2/10	3/10																		
%		0	0			10	20	0																		

FIGURE 5-9. RAW DATA SHEET – SAMPLE D, ULTRASONIC SHEAR WAVE SCANS (Continued)

	Flaw I.D	Flaw Size	0202	0206	0208	03E1	03E2	03E3	03E4	03E5	03E6	03E7	03E8	03E9	03E10	03E11	03E12	03E13	03E14	03E15	03E16	03E17	03E18	03E19	03E20	0402	0108
			TECHNICIAN I D																								
*	D2-10	<.02	0	0	0	0	1	0	0	1	0	0	1	0	0	1	1	1	0	1	1	1	1	0	1	0	0
*	D2-5	<.02	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0	1	0	0
*	D2-12	.02	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0
*	D1-24	.03	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
*	D1-8	.03	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
*	D1-48	.03	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0	1	0	0	1	0	1	0	1	0	0
*	D1-69	.03	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0
*	D1-34	.04	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0	0	0	0	0	1	0	1	1	0	0
*	D1-68	.04	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0
*	D2-3	.04	0	0	0	0	0	0	1	0	1	0	0	0	1	0	1	0	0	1	0	0	1	1	1	0	0
	F		1	7	8	0	6	2	14	10	18	12	5	3	12	0	13	15	6	33	12	15	54	16	149	0	0
	Σ/N		0/10	0/10	1/10	0/10	3/10	0/10	5/10	1/10	4/10	2/10	1/10	1/10	1/10	2/10	2/10	3/10	0/10	3/10	2/10	3/10	6/10	2/10	10/10	0/10	0/10
	%		0	0	10	0	30	0	50	10	40	20	10	10	10	20	20	30	0	30	20	30	60	20	100	0	0

FIGURE 5-10. RAW DATA SHEET - SAMPLE D, MANUAL EDDY CURRENT BOLT HOLE SCANS

		TECHNICIAN ID																					
Flaw ID	Flaw Size	0501	0502	0505	0507	0604	0605	0702	0703	0705	0803	0805	0806	0902	0905	0909	1031	1037	1103	1113	1118	1121	1203
* D2-10	<.02	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
* D2-5	<.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
* D2-12	.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
* D1-24	.03	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
* D1-8	.03	0	0	0	-	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0
* D1-48	.03	0	0	0	-	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0
* D1-69	.03	0	1	0	-	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
* D1-34	.04	1	0	0	-	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	1	1	0
* D1-68	.04	0	0	0	-	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
* D2-3	.04	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	1
F		1	2	1	4	0	0	4	0	13	8	16	12	4	0	5	7	0	0	1	1	3	1
Σ/N		1/10	1/10	3/10	0/4	0/10	0/10	0/10	0/10	4/10	1/10	3/10	1/10	0/10	1/10	0/10	1/10	0/10	0/10	0/10	1/10	2/10	1/10
%		10	10	0	0	0	0	0	0	40	10	30	10	0	10	0	10	0	0	0	10	20	10

FIGURE 5-10. RAW DATA SHEET - SAMPLE D, MANUAL EDDY CURRENT BOLT HOLE SCANS (Continued)

Flaw ID	Flaw Size	1304	1310	1311	1324	1326	1330	1317-.	1403	1503	16E1	16E3	16E4	16E5	16E9	16E10	16PIE	1701	1805	1806	1807	1810	1811	1819	1820
* 02-10	<.02	0	0	1	0	0	1	0	0	0	0	0	1	0	0	0	0	1	1	0	0	0	1	0	0
* 02-5	<.02	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
* 02-12	.02	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
* 01-24	.03	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	—	0	1	0	0	0	0	0	0
* 01-8	.03	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0
* 01-48	.03	0	0	0	1	0	0	1	0	1	1	0	0	0	0	0	—	0	0	0	0	0	0	0	0
* 01-69	.03	0	1	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
* 01-34	.04	0	1	1	1	0	0	0	0	0	1	0	0	0	0	1	—	0	0	0	0	0	0	0	0
* 01-68	.04	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
* 02-3	.04	0	1	1	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0
F		7	11	18	21	14	23	8	1	7	38	1	1	0	12	12	1	7	23	4	1	2	4	0	2
Σ/N		1/10	5/10	3/10	5/10	0/10	4/10	3/10	2/10	1/10	5/10	0/10	1/10	0/10	0/10	1/10	0/7	2/10	3/10	1/10	1/10	0/10	2/10	0/10	0/10
%		10	50	30	50	0	40	30	20	10	50	0	10	0	0	10	0	20	30	10	10	0	20	0	0

FIGURE 5-10. RAW DATA SHEET - SAMPLE D, MANUAL EDDY CURRENT BOLT HOLE SCANS (Continued)

	Flaw ID	Flaw Size	TECHNICIAN ID																								Σ/N	%
			100 B																									
*	D2-10	<.02	0																								19/71	26.8
*	D2-5	<.02	0																								5/71	7.0
*	D2-12	.02	0																								6/71	8.5
*	D1-24	.03	0																								4/69	5.8
*	D1-8	.03	0																								10/70	14.3
*	D1-48	.03	0																								12/69	17.4
*	D1-69	.03	0																								9/70	12.9
*	D1-34	.04	0																								16/69	23.2
*	D1-68	.04	0																								8/70	11.4
*	D2-3	.04	0																								17/71	23.9
	F		3																									
	Σ/N		0/10																									
	%		0																									

FIGURE 5-10. RAW DATA SHEET - SAMPLE D, MANUAL EDDY CURRENT BOLT HOLE SCANS (Continued)

	Flaw ID	Flaw Size	1102	1115	1301	1319	1403	1502	16P1U	16E3	1811	Σ/N	%
			TECHNICIAN ID										
*	D2-10	<.02	0	0	1	1	0	0	0	0	1	3/9	33.3
*	D2-5	<.02	0	0	0	0	0	0	0	0	1	1/9	11.1
*	D2-12	.02	0	0	0	1	0	0	0	0	0	1/9	11.1
*	D1-24	.03	0	0	0	0	0	0	1	0	1	2/9	22.2
*	D1-8	.03	0	0	0	0	0	1	1	0	0	2/9	22.2
*	D1-43	.03	1	0	0	0	0	0	1	1	1	4/9	44.4
*	D1-69	.03	0	0	0	0	0	0	0	0	1	1/9	11.1
*	D1-34	.04	1	0	0	0	0	0	0	0	1	2/9	22.2
*	D1-65	.04	0	0	0	0	0	0	0	0	1	1/9	11.1
*	D2-3	.04	0	0	0	1	0	0	0	0	1	2/9	22.2
	F		2	0	9	14	1	3	13	0	34		
	Σ/N		2/10	0/10	1/10	3/10	0/10	1/10	3/10	1/10	8/10		
	%		20	0	10	30	0	10	30	10	80		

FIGURE 5-11. RAW DATA SHEET - SAMPLE D, EDDY CURRENT BOLT HOLE SCANS

	Flaw ID	Flaw Size	0201	0202	0207	0208	0209	03E1	03E2	03E3	03E4	03E5	03E6	03E7	03E8	03E9	03E10	03E11	03E12	03E13	03E14	03E15	03E16	03E17	03E18	03E19	03E20	0401	0402	0408
			TECHNICIAN ID																											
*	E1-21	<.02	0	0	0	0	0	0	0	0	1	1	1	0	0	1	0	0	1	0	0	1	0	-	1	0	1	1	0	0
	E1-47	<.02	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	-	0	0	1	1	0	0
*	E2-7	<.02	0	0	0	0	0	0	0	-	-	0	0	0	0	0	1	0	0	0	0	-	0	0	1	0	1	-	0	0
*	E2-36	.02	0	0	0	0	0	0	0	-	-	1	0	1	1	1	0	1	0	0	0	-	0	1	0	0	1	-	0	0
*	E2-6	.03	0	0	1	0	0	0	0	-	-	0	0	1	0	1	0	0	0	1	1	-	0	1	0	0	1	-	0	0
*	E2-44	.03	0	0	0	0	0	0	0	-	-	1	0	0	1	0	0	0	0	0	0	-	0	1	0	0	1	-	0	0
*	E2-64	.04	1	0	0	0	0	0	1	-	-	0	1	0	1	0	0	0	1	0	0	-	0	0	1	1	1	1	0	0
*	E2-20	.04	0	1	0	0	0	0	0	-	-	0	1	1	0	1	0	0	0	0	1	-	0	-	1	0	1	-	0	0
*	E2-23	.05	0	0	0	0	0	0	1	0	-	0	1	0	0	0	0	0	1	1	0	-	0	0	1	0	1	0	0	0
*	E2-26	.05	0	0	1	0	0	0	0	-	-	0	1	1	0	1	0	0	1	0	1	-	0	1	0	0	1	-	0	0
*	E2-55	.05	0	0	0	0	0	0	0	0	-	0	1	0	0	0	0	0	0	1	0	-	0	0	1	0	1	1	0	0
*	E2-63	.05	0	0	0	0	0	0	0	-	-	0	1	0	0	0	1	0	0	0	0	-	0	0	0	0	1	0	0	0
*	E2-54	.06	1	0	0	0	0	0	0	0	-	0	1	0	0	1	0	0	0	0	0	-	0	0	1	0	1	1	0	0
*	E2-67	.06	0	0	0	0	0	0	0	-	-	0	1	1	0	0	1	0	0	0	1	-	0	1	1	0	1	-	0	0
	E1-49	.07	0	0	0	1	0	0	1	0	1	0	0	0	0	1	0	0	1	0	1	1	0	-	1	0	1	1	0	0
*	E1-23	.08	0	0	0	1	0	0	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	-	1	0	1	0	0	0
*	E2-68	.08	0	0	0	1	0	0	0	0	-	0	1	0	0	0	0	0	1	1	0	-	0	1	1	0	1	0	0	0
*	E1-22	.09	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	-	0	0	1	0	0	0
*	E1-8	.10	0	0	0	0	0	0	1	1	0	0	0	0	0	1	0	0	1	0	0	0	0	-	1	0	1	0	0	0
*	E1-28	.10	0	0	0	0	0	0	1	1	1	0	0	0	0	1	0	0	1	0	1	0	0	-	1	1	1	0	0	0
*	E2-80	.10	0	0	0	0	0	0	0	-	-	1	1	0	0	0	1	0	0	0	1	-	0	0	1	0	1	-	0	0
	E2-69	.12	0	0	0	1	0	0	1	1	-	0	0	0	0	1	1	0	1	1	0	-	0	1	1	0	1	1	0	0
	E1-19	.14	0	0	0	0	0	0	1	1	1	1	0	1	0	1	1	0	1	0	1	1	0	-	1	0	1	1	0	0
	E1-14	.18	0	0	0	1	1	0	1	1	1	0	0	1	0	1	1	0	0	1	1	1	0	-	1	0	1	1	0	0
	E1-32	.20	1	1	0	0	0	0	1	1	1	0	0	1	1	1	1	1	1	1	1	0	1	-	1	0	1	1	0	0
*	E1-1	.25	1	0	0	1	1	0	1	1	1	0	0	1	0	0	1	1	1	1	1	1	0	-	1	0	1	1	0	0
	E2-3	.27	0	0	1	0	1	0	1	1	-	0	1	0	0	1	1	1	1	1	0	-	0	1	1	0	1	1	0	0
	F		1	10	2	12	1	5	19	3	18	13	43	13	22	40	17	4	31	23	10	3	17	33	59	12	93	18	0	0
	E/N		4/27	2/27	3/27	6/27	3/27	0/27	14/27	8/17	8/11	5/27	12/27	9/27	4/27	17/27	11/27	4/27	13/27	9/27	11/27	5/11	1/27	9/17	20/27	2/27	27/27	12/19	0/27	0/27
	%		15	7	11	22	11	0	52	47	73	19	44	33	15	63	41	15	48	33	41	45	4	53	74	7	100	63	0	0

FIGURE 5-12. RAW DATA SHEET - SAMPLE E, MANUAL EDDY CURRENT BOLT HOLE SCANS

	Flaw ID	Flaw Size	TECHNICIAN ID																				
			0501	0502	0506	0507	0604	0605	0701	0702	0703	0803	0809	0902	0906	0909	0910	0915	1002	1013	1103	1113	1117	1118	1121
*	E1-27	<.02	0	0	0	1	-	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
	E1-47	<.02	0	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1
*	E2-7	<.02	0	0	0	0	0	-	0	0	0	1	0	0	0	0	1	0	0	0	0	0	1	0	0
*	E2-36	.02	0	0	0	1	0	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
*	E2-6	.03	0	0	0	0	0	-	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
*	E2-44	.03	0	0	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
*	E2-84	.04	0	0	1	0	0	-	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
*	E2-20	.04	0	0	1	0	0	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
*	E2-23	.05	0	0	0	1	0	-	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
*	E2-26	.05	0	0	1	0	0	-	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
*	E2-55	.05	0	0	0	0	0	-	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
*	E2-63	.05	1	0	0	0	0	-	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
*	E2-54	.06	0	0	0	0	0	-	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
*	E2-67	.06	0	0	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	E1-49	.07	0	0	0	0	-	0	1	0	0	1	0	0	0	0	1	0	0	0	0	1	1	1	1
*	E1-23	.08	0	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
*	E2-68	.08	0	0	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
*	E1-22	.09	0	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
*	E1-8	.10	0	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
*	E1-28	.10	0	0	1	0	-	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	1	1
*	E2-80	.10	1	0	1	0	0	-	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	E2-69	.12	1	0	0	0	1	-	1	0	0	0	0	1	0	0	0	0	0	0	1	1	1	1	1
	E1-19	.14	1	1	0	1	-	1	1	1	0	0	0	0	0	0	1	0	0	0	0	1	1	1	1
	E1-14	.18	0	0	0	0	-	0	1	1	0	0	0	0	0	1	1	0	0	0	1	1	1	1	1
	E1-32	.20	1	1	0	1	-	1	1	1	0	0	0	1	0	1	1	0	0	0	1	1	1	1	1
*	E1-1	.25	0	0	1	1	-	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1
	E2-3	.27	1	1	0	1	1	-	0	1	1	1	0	1	0	0	1	1	0	0	1	1	1	1	1
	F		1	4	19	20	3	0	21	3	2	7	8	0	3	3	9	8	0	0	2	3	2	2	3
	Σ/N		6/27	3/27	6/27	7/27	2/16	2/11	8/27	5/27	2/27	4/27	1/27	3/27	2/27	2/27	9/27	1/27	0/27	0/27	6/27	12/27	13/27	12/27	14/27
	%		22	11	22	26	13	18	30	19	7	15	4	11	7	7	33	4	0	0	22	44	48	44	52

FIGURE 5-12. RAW DATA SHEET - SAMPLE E, MANUAL EDDY CURRENT BOLT HOLE SCANS (Continued)

			TECHNICIAN ID																											
	Flaw ID	Flaw Size	1201	1207	1208	1301	1303	1304	1308	1311	1312	1313	1318	1320	1321	1317	1323	1401	1402	1501	16E1	16E3	16E4	16E5	16E6	16E7	16E8U	16E9	16ED	16PIE
*	E1-27	<.02	0	0	0	0	0	0	0	1	0	1	0	0	0	1	0	0	0	0	1	0	0	0	0	1	1	0	0	0
	E1-47	<.02	0	0	0	0	0	0	0	-	0	1	1	0	0	0	0	0	1	0	1	0	0	0	0	1	0	0	1	0
*	E2-7	<.02	0	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	-	-	-	0	0	0
*	E2-36	.02	0	-	0	1	0	0	1	0	0	0	0	-	0	0	0	0	0	0	0	-	0	0	-	-	-	0	0	0
*	E2-6	.03	0	-	0	0	0	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0	1	0	-	-	-	0	0	0
*	E2-44	.03	0	-	0	1	0	0	0	0	0	0	0	-	0	0	0	0	0	0	0	-	0	0	-	-	-	0	0	0
*	E2-84	.04	0	-	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	1	0	-	-	0	0	0	0
*	E2-20	.04	0	-	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	-	-	-	0	0	0
*	E2-23	.05	0	-	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	1	0	-	1	1	0	0	0
*	E2-26	.05	0	-	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	-	-	-	0	0	0
*	E2-55	.05	0	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	-	0	0	0	0	0
*	E2-63	.05	0	-	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1	0	1	0	0	0	-	-	0	0	0	0
*	E2-54	.06	0	-	0	0	0	0	0	0	0	1	1	1	0	1	0	1	0	0	1	0	0	0	-	1	1	0	0	0
*	E2-67	.06	0	-	0	0	0	1	1	1	1	0	0	1	0	0	0	0	0	0	1	-	0	0	-	-	-	0	0	0
	E1-49	.07	0	0	0	0	0	0	0	-	0	0	1	0	0	0	1	1	0	0	1	1	1	0	0	1	1	1	1	0
*	E1-23	.03	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	1	1	1	0	0	1	1	0	1	0
*	E2-68	.08	0	-	1	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	-	1	1	0	0	0
*	E1-22	.09	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	0	0	0
*	E1-8	.10	0	1	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	1	1	0	0	1	0	0	0	0
*	E1-28	.10	0	1	1	0	0	1	0	0	1	0	0	0	0	0	1	0	0	0	1	0	1	0	0	1	0	1	0	1
*	E2-80	.10	0	-	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	-	0	0	-	-	-	0	0	0
	E2-69	.12	0	-	1	1	0	0	1	1	0	0	0	0	0	1	0	1	1	1	1	1	1	1	-	1	1	1	1	1
	E1-19	.14	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1	0	1	1	0	1	0
	E1-14	.18	0	1	1	1	0	0	0	1	0	0	1	0	1	0	1	0	1	1	1	1	1	1	1	0	1	0	1	1
	E1-32	.20	0	1	1	1	0	0	1	-	1	0	0	0	1	1	0	1	1	1	1	1	1	1	1	1	1	0	1	0
*	E1-1	.25	0	1	1	1	1	0	0	1	0	1	0	0	1	0	1	0	0	1	1	0	1	0	1	1	1	0	1	1
	E2-3	.27	0	-	1	1	0	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	-	1	0	1	1	0
	F		0	1	3	9	5	4	28	17	3	28	16	12	2	14	11	16	13	6	71	1	18	1	0	33	13	3	3	2
	Σ/N		0/27	6/11	11/27	10/27	1/21	3/21	6/29	11/24	6/27	6/27	7/27	4/25	4/27	5/27	6/27	6/27	7/27	6/27	19/27	8/23	15/27	5/21	3/11	15/17	12/19	4/27	9/27	4/27
	%		0	55	41	37	4	11	22	46	22	22	26	16	15	19	22	22	26	22	70	35	56	19	27	89	63	15	33	15

FIGURE 5-12. RAW DATA SHEET - SAMPLE E, MANUAL EDDY CURRENT BOLT HOLE SCANS (Continued)

	Flaw ID	Flaw Size	1702	1803	1804	1805	1806	1807	1810	1811	1812	1813	1819	1820	1834	1901	1904	2001	2002	2003	2005	2008	2009	2011	2012	2014	2014	2015	2103
			TECHNICIAN ID																										
*	E1-21	<.02	1	0	0	0	1	0	1	0	-	1	0	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0
	E1-47	<.02	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	1
*	E2-7	<.02	1	0	0	1	1	1	0	0	-	0	0	0	0	-	0	0	0	0	1	1	0	0	0	0	0	0	0
*	E2-36	.02	0	0	0	1	0	0	0	0	-	0	0	0	-	-	-	0	0	1	0	0	0	0	0	0	0	0	0
*	E2-6	.03	0	0	0	1	0	0	0	0	-	0	0	0	0	-	0	0	1	0	0	0	0	0	0	0	0	0	0
*	E2-44	.03	0	0	0	1	0	0	0	0	-	0	0	0	-	-	-	0	0	0	0	1	0	0	0	0	0	0	0
*	E2-84	.04	1	0	0	1	0	1	0	0	-	1	0	0	1	-	1	0	0	0	0	0	0	0	1	0	0	0	0
*	E2-20	.04	0	0	0	1	1	0	0	0	-	0	0	0	1	--	0	0	1	0	0	0	0	0	1	0	0	0	0
*	E2-23	.05	0	0	0	0	0	1	0	0	-	1	0	0	0	-	0	1	0	0	1	0	0	0	1	0	0	0	0
*	E2-26	.05	0	0	0	1	0	0	1	0	-	0	0	0	1	-	0	0	0	0	0	0	0	0	0	0	0	0	0
*	E2-55	.05	0	0	0	1	0	0	0	0	-	0	0	0	0	-	0	0	0	0	0	0	0	0	1	0	0	0	0
*	E2-63	.05	1	0	0	0	0	1	0	0	-	0	0	0	0	-	0	0	0	0	0	0	0	0	1	0	0	0	1
*	E2-54	.06	1	0	0	0	0	0	0	1	-	1	0	0	1	-	1	0	0	0	0	0	0	0	1	0	0	0	0
*	E2-67	.06	0	0	0	1	0	0	0	0	-	0	0	0	-	--	-	0	0	0	0	1	0	0	1	0	0	0	0
	E1-49	.07	1	0	0	0	0	0	0	1	0	0	0	0	0	1	0	1	0	0	1	0	0	0	0	0	0	1	1
*	E1-23	.08	1	0	0	0	1	0	0	0	-	0	0	0	1	1	0	0	0	0	0	0	0	0	1	0	1	0	0
*	E2-68	.08	1	0	0	0	0	0	0	0	-	0	0	0	0	-	0	0	0	0	0	0	0	0	1	0	0	0	0
*	E1-22	.09	0	0	0	0	0	1	0	0	-	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
*	E1-8	.10	1	0	0	1	1	0	0	1	-	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0	1	0	0
*	E1-28	.10	0	1	0	1	1	0	0	0	0	1	0	0	0	1	0	1	0	0	1	0	0	0	1	0	0	0	0
*	E2-80	.10	0	0	0	1	0	0	0	0	-	1	0	0	-	-	-	0	0	0	0	1	0	0	1	1	1	0	0
	E2-69	.12	1	1	1	1	0	0	0	0	-	1	0	1	1	-	1	1	1	0	1	0	0	0	1	0	1	0	1
	E1-19	.14	1	0	0	1	0	0	0	0	-	1	0	0	1	0	1	1	0	0	0	0	0	0	1	0	1	0	0
	E1-14	.18	1	1	1	1	1	0	0	1	-	1	0	0	0	-	0	1	0	0	0	0	0	0	0	1	1	0	0
	E1-32	.20	1	1	0	1	0	1	1	0	0	1	0	0	1	1	0	1	1	1	1	0	0	0	0	1	1	1	0
*	E1-1	.25	1	1	0	1	1	1	0	1	-	1	0	0	1	0	0	1	0	0	0	0	1	0	0	0	1	0	1
	E2-3	.27	1	0	1	1	1	0	0	0	-	1	0	1	1	-	0	1	1	1	0	0	0	0	1	1	1	1	1
	F		26	1	4	76	40	29	8	5	1	11	0	4	38	18	31	2	20	4	64	8	9	0	52	6	2	3	11
	Σ/N		16/27	5/27	3/27	18/27	9/27	7/27	3/27	5/27	0/4	12/27	0/27	2/27	14/23	7/10	6/23	12/27	6/27	3/27	6/27	4/27	1/27	0/27	14/27	4/27	9/27	3/27	6/27
	%		59	19	11	67	33	26	11	19	0	44	0	7	61	70	26	44	22	11	22	15	4	0	52	15	33	11	22

FIGURE 5-12. RAW DATA SHEET - SAMPLE E, MANUAL EDDY CURRENT BOLT HOLE SCANS (Continued)

TECHNICIAN ID

	Flaw ID	Flaw Size	2104		2203	2204	2206	Σ/N	%
*	E1 21	<.02	0		1	0	0	28/106	26.4
	E1 47	<.02	0		1	0	0	22/106	20.8
*	E2 7	<.02	0		0	1	1	15/98	15.3
*	E2 36	.02	0		0	0	0	12/94	12.8
*	E2 6	.03	0		0	0	1	14/98	14.3
*	E2 44	.03	0		0	0	0	7/94	7.4
*	E2 84	.04	0		1	0	1	25/100	25.0
*	E2 30	.04	0		1	1	1	18/97	18.6
*	E2 23	.05	0		1	0	1	21/102	20.6
*	E2 26	.05	0		1	1	1	18/98	18.4
*	E2 55	.05	0		0	0	1	10/102	9.8
*	E2 63	.05	0		1	0	1	15/100	15.0
*	E2 54	.06	0		0	0	1	22/102	21.6
*	E2 67	.06	0		0	1	1	22/95	23.2
	E1 49	.07	0		1	0	0	34/106	32.1
*	E1 23	.08	0		0	0	0	24/106	22.6
*	E2 68	.08	0		1	0	1	16/103	15.5
*	E1-22	.09	0		0	1	0	15/106	14.2
*	E1-8	.10	0		1	0	0	24/101	24.5
*	E1-28	.10	0		1	0	0	32/107	29.9
*	E2 80	.10	0		1	1	1	20/96	20.8
	E2 69	.12	0		1	0	1	53/100	53.0
	E1 19	.14	0		0	0	0	42/106	39.6
	E1 14	.18	0		0	0	1	50/105	47.6
	E1 32	.20	0		1	0	1	66/106	62.3
*	E1-1	.25	0		0	0	1	52/106	49.1
	E2 3	.27	0		1	1	1	67/102	65.7
	F		0		58	27	52		
	Σ/N		0/27		15/27	7/27	17/27		
	%		0		56	26	63		

FIGURE 5-12. RAW DATA SHEET - SAMPLE E, MANUAL EDDY CURRENT BOLT HOLE SCANS (Continued)

	Flaw ID	Flaw Size	TECHNICIAN ID 1102	1113	1115	1301	1314	1401	1402	1501	16E1	16E2U	16E3	16E4	16F1	1703	1803	1811	1820	2002	2007	2002/3	2105	2213	E/N	%
*	E1-27	<.02	0	0	0	0	1	1	1	1	1	0	0	1	0	1	0	1	0	0	0	1	0	1	10/22	45.5
	E1-47	<.02	1	1	0	1	1	0	0	0	1	0	1	0	0	1	0	1	0	1	0	1	1	0	11/22	50.0
*	E2-7	<.02	0	-	0	0	0		-	0	1	-	0	0	0	1	0	1	0	0	0	0	0	1	5/19	26.3
*	E2-36	.02	0	-	0	0	0	0	-	0	0	-	0	0	0	0	0	1	1	0	0	0	0	0	2/19	10.5
*	E2-6	.03	0	-	0	-	0	1	-	0	1	-	0	0	0	1	0	1	0	0	0	1	0	1	6/18	33.3
*	E2-44	.03	0	-	0	0	0	0	-	0	0	-	0	0	0	1	0	0	0	0	0	0	0	1	2/19	10.5
*	E2-84	.04	0	-	0	0	1	0	-	1	1	-	0	1	0	1	0	1	0	0	0	1	0	1	8/19	42.1
*	E2-20	.04	0	-	0	0	1	0	-	1	1	-	0	0	0	1	0	1	0	0	0	1	0	1	6/19	31.6
*	E2-23	.05	0	-	0	0	-	0	1	1	1	-	0	1	1	0	0	1	1	1	0	1	0	1	10/19	52.6
*	E2-26	.05	0	-	0	0	1	0	-	0	1	-	0	0	0	1	0	1	0	0	0	1	0	1	6/19	31.6
*	E2-55	.05	0	-	0	0	-	0	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0	0	0/19	0
*	E2-63	.05	0	-	0	0	0	0	1	0	0	-	0	0	0	1	0	0	0	0	0	0	0	0	2/20	10.0
*	E2-56	.06	0	-	0	0	-	0	0	0	1	-	0	1	0	1	0	0	0	1	0	0	0	1	5/19	26.3
*	E2-67	.06	0	-	0	1	0	1	-	0	1	-	1	0	0	1	0	1	1	1	0	0	1	1	10/19	52.6
	E1-49	.07	1	1	0	0	1	0	0	0	1	0	1	1	-	1	1	1	1	1	0	1	1	1	14/21	66.7
*	E1-23	.08	1	1	0	1	1	1	1	0	1	0	0	1	0	1	1	1	0	0	0	0	0	1	12/22	54.5
*	E2-68	.08	0	-	0	0	-	0	1	1	1	-	0	1	0	1	0	1	0	0	0	1	0	1	8/19	42.1
*	E1-22	.09	1	1	0	1	0	0	1	0	1	0	0	1	0	1	1	0	1	0	0	0	1	0	10/22	45.5
*	E1-8	.10	1	1	1	1	1	1	1	0	0	1	0	0	1	0	1	1	1	0	0	1	1	0	14/22	63.6
*	E1-28	.10	1	1	1	1	1	1	1	1	1	0	0	0	0	1	0	1	0	0	0	1	1	1	14/22	63.6
*	E2-80	.10	0	-	0	0	0	0	-	0	1	-	0	1	1	1	0	1	0	0	0	0	0	1	6/19	31.6
	E2-69	.12	1	-	1	1	1	1	1	1	1	-	1	1	0	1	1	1	0	0	0	1	1	1	15/20	75.0
	E1-19	.14	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	0	0	0	1	1	1	18/22	81.8
	E1-14	.19	1	1	1	1	1	1	1	0	1	1	1	1	0	1	1	1	0	0	0	1	1	1	17/22	77.3
	E1-32	.20	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	0	1	1	1	20/22	90.9
*	E1-1	.25	1	1	1	1	1	1	1	0	0	1	1	1	0	1	1	1	1	0	0	1	1	1	17/22	77.3
	E2-3	.27	1	-	0	1	1	1	1	1	1	-	1	1	1	1	1	0	1	0	1	1	1	1	7/20	85.0
	F		3	1	1	2	13	23	28	17	48	3	7	22	9	66	4	51	14	24	0	57	5	50		
	E/N		12/27	10/11	8/27	12/26	15/23	13/27	14/18	10/27	21/27	5/11	8/27	15/27	6/26	23/27	9/27	21/27	9/27	6/27	1/27	17/27	12/27	21/27		
	%		44	91	30	46	65	48	78	37	78	45	30	56	23	85	33	78	33	22	4	63	44	78		

FIGURF 5-13. RAW DATA SHEET - SAMPLE E, AUTOMATIC EDDY CURRENT BOLT HOLE SCANS

Flaw ID	Flaw Size	0202	020[illegible]	0203	03E1	03E2	03E3	03E4	03E5	03E6	03E7	03E8	03E9	03E10	03E11	03E12	03E13	03E14	03E15	03E16	03E17	03E18	03E19	03E20
6-66	.015	0	0	1	0	1	1	-	1	1	1	1	0	0	1	0	[illegible]	0	0	0	1	1	0	-
* 6-67	.015	0	1	1	0	0	0	-	1	0	0	1	0	1	1	0	1	0	1	0	1	0	0	1
* 6-77	.015	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	-
* 1-14	.03	0	0	0	0	-	0	-	0	0	0	0	0	0	0	0	1	0	0	1	1	1	0	-
5-26	.03	0	0	0	0	0	0	-	0	1	0	0	0	0	0	0	0	0	0	0	0	-	0	-
5-68	.03	0	0	0	0	1	0	-	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0
5-81	.03	0	0	0	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-
5-82	.03	0	0	0	0	0	1	-	0	0	1	1	0	0	0	0	0	0	0	0	0	1	0	-
* 5-84	.03	0	0	0	0	0	1	-	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	-
6-70	.03	0	0	0	1	0	0	-	0	0	1	0	0	0	0	0	0	0	0	0	1	0	1	1
6-72	.03	0	0	0	0	0	0	-	0	0	0	1	0	0	0	0	1	1	0	0	1	0	0	1
1-15	.04	0	0	0	0	-	0	-	0	0	0	1	0	0	0	0	1	0	0	0	1	0	0	-
* 2-8	.04	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	-	0	0	-
* 2-14	.04	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	-
* B1-18	.04	0	-	0	1	0	-	-	1	1	0	0	1	0	0	1	0	0	0	0	1	0	0	-
1-71	.05	0	1	1	0	-	0	-	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	-
1-73	.05	0	0	0	0	-	0	-	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	-
* 5-65	.05	0	0	0	0	0	0	-	1	0	0	1	0	0	0	0	1	0	0	0	-	1	0	0
6-15	.05	0	0	0	0	0	0	-	0	1	0	1	0	1	0	0	1	0	0	0	-	0	0	-
6-65	.05	0	0	1	0	1	0	-	0	1	0	0	0	0	0	0	0	0	0	1	1	1	0	1
1-11	.06	0	0	1	0	-	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	-
1-12	.06	0	0	1	0	-	0	0	0	0	0	0	1	0	0	1	0	1	0	1	0	0	0	-
2-66	.06	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	1	-	0	-
2-86	.06	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	-	0	-
* B1-21	.06	0	-	0	0	0	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	-
6-76	.06	0	0	0	0	0	0	-	1	0	0	1	0	0	0	1	0	0	1	0	0	0	0	-
1-9	.07	0	1	0	0	-	0	0	0	1	0	0	0	0	0	0	0	1	0	1	1	0	0	-
1-24	.07	0	0	0	0	-	0	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	-
1-66	.07	0	1	0	0	-	0	0	1	0	0	1	1	0	0	0	0	0	0	0	1	0	1	-
A1-22	.08	0	-	-	0	-	0	0	0	1	0	0	1	1	1	1	0	0	0	0	0	0	0	-
6-71	.09	0	0	0	0	0	0	-	0	1	0	1	0	1	1	0	0	0	0	0	0	1	1	-
1-79	.10	0	0	0	0	-	0	-	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	-
2-20	.10	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	-	0	-
2-18	.11	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	-	0	-
5-10	.11	0	0	0	0	1	0	-	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	1
A1-21	.12	0	-	-	0	-	0	0	0	1	1	0	1	1	1	1	0	0	0	0	0	1	1	0
2-72	.13	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	-	0	-
1-23	.15	0	0	0	0	-	0	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	-
2-24	.17	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	-
1-69	.18	0	0	0	0	-	1	1	0	1	0	1	1	1	0	1	0	1	0	0	1	0	0	-
A1-1	.185	0	0	0	0	-	0	0	0	1	0	0	1	1	1	0	0	0	0	0	0	0	1	-
6-13	.23	0	1	0	0	1	0	-	1	0	0	1	0	0	1	0	1	0	0	0	1	1	0	1
6-84	.37	0	1	1	0	0	0	-	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
F		0	3	4	12	2	8	1	18	46	23	37	7	12	3	6	19	9	4	8	59	24	21	21
Σ/N		0/43	6/39	7/41	3/43	8/28	5/41	1/17	7/45	14/46	4/43	18/[illegible]	7/43	8/43	7/43	7/43	7/43	8/43	4/43	5/45	16/40	13/37	10/43	7/10
%		0	15	17	7	29	12	6	16	30	9	44	16	19	16	16	16	19	9	17	40	35	23	70

FIGURE 5-14. RAW DATA SHEET - SAMPLE F, MANUAL EDDY CURRENT BOLT HOLE SCANS

	Flaw ID	Flaw Size	C402	C405	C406	C407	C501	C506	C504	C601	C702	C703	C503	C506	C507	C501	C502	C503	C506	C514	1001
			TECHNICIAN ID																		
	6-66	.015	0	0	1	–	0	0	0	0	0	0	0	0	–	0	0	0	0	0	0
*	6-67	.015	0	0	0	–	0	0	0	0	0	0	0	0	–	0	0	0	0	1	0
*	6-77	.015	0	0	0	–	0	0	0	0	0	0	0	0	–	0	0	0	0	0	0
*	1-14	.03	0	0	1	–	0	0	0	0	0	0	0	–	1	0	0	0	0	0	0
	5-26	.03	0	0	1	–	1	0	0	0	0	0	0	0	–	0	0	0	0	0	1
	5-68	.03	0	0	0	–	0	0	0	0	0	0	0	0	–	0	0	0	0	0	0
	5-81	.03	0	0	1	–	0	0	0	0	0	0	0	0	–	0	0	0	1	0	0
	5-82	.03	0	0	0	–	0	0	0	0	0	0	0	0	–	0	0	0	0	0	1
*	5-84	.03	0	0	1	–	0	0	0	0	0	0	0	0	–	0	0	0	0	0	0
	6-70	.03	0	0	0	–	0	0	0	0	1	0	0	0	–	0	0	0	0	0	0
	6-72	.03	0	0	1	–	0	0	0	0	0	0	0	0	–	0	0	0	0	0	0
	1-15	.04	0	0	0	–	0	0	1	0	0	0	0	–	0	0	0	0	0	0	0
*	2-8	.04	0	0	0	0	0	0	0	0	0	0	0	–	0	0	0	0	0	0	0
*	2-14	.04	0	0	0	0	0	0	0	0	0	0	0	–	0	0	0	0	0	1	0
*	B1-18	.04	0	0	0	–	0	0	0	0	0	0	0	0	–	0	0	0	0	0	0
	1-71	.05	0	0	0	–	0	0	0	0	0	0	0	–	0	0	0	0	0	0	0
	1-73	.05	0	0	0	–	0	0	0	0	0	0	0	–	0	0	0	0	0	0	1
*	5-65	.05	0	0	0	–	0	0	0	0	0	0	0	0	–	0	0	0	0	0	0
	6-15	.05	0	0	1	–	0	0	0	0	0	0	0	0	–	0	0	0	0	0	0
	6-65	.05	0	0	1	–	0	0	0	0	0	0	0	0	–	0	0	0	0	0	1
	1-11	.06	0	0	0	–	0	0	0	0	0	0	0	–	0	0	0	0	0	0	0
	1-12	.06	0	0	0	–	0	0	0	0	0	0	0	–	0	0	0	0	0	0	0
	2-26	.06	0	0	1	0	0	0	0	0	0	0	1	–	0	0	0	0	0	0	1
	2-86	.06	0	0	1	0	0	0	0	0	0	0	0	–	0	0	0	0	0	0	0
*	B1-21	.06	0	0	1	–	0	0	0	0	0	0	0	0	–	0	0	0	0	0	0
	6-76	.06	0	0	1	–	0	0	0	0	0	0	0	0	–	1	0	0	1	0	0
	1-9	.07	0	0	0	–	0	0	0	0	0	0	0	–	0	0	0	0	0	0	0
	1-24	.07	0	0	1	–	0	0	0	0	0	0	0	–	0	0	0	0	0	0	1
	1-66	.07	0	0	1	–	1	0	0	0	0	0	0	–	–	0	0	0	0	0	0
	A1-22	.08	0	0	0	–	0	0	0	1	0	0	1	–	0	0	0	0	0	0	0
	6-71	.09	0	0	1	–	0	0	0	0	0	0	0	0	–	1	0	0	1	0	0
	1-79	.10	0	0	0	–	0	0	1	0	0	0	0	–	1	0	0	0	0	0	1
	2-20	.10	0	0	0	1	1	0	0	0	1	0	1	–	0	0	0	0	1	1	0
	2-18	.11	0	0	0	1	1	0	0	0	0	0	1	–	0	0	0	0	0	1	0
	5-10	.11	0	0	0	–	0	0	0	0	0	0	0	0	–	0	0	0	0	0	0
	A1-21	.12	0	0	0	–	0	0	0	1	0	0	1	–	0	0	0	0	0	0	0
	2-72	.13	0	0	0	1	1	0	0	0	0	0	0	–	0	0	0	1	0	0	1
	1-23	.15	0	0	0	–	0	0	1	0	0	0	0	–	1	0	0	0	0	0	1
	2-24	.17	0	0	1	0	0	0	0	0	0	0	0	–	1	0	0	0	0	0	0
	1-69	.18	0	0	1	–	0	0	1	1	0	0	0	–	0	0	0	0	0	0	1
	A1-1	.185	0	0	0	–	0	0	0	1	0	0	0	–	0	0	0	0	0	0	0
	6-73	.23	0	0	1	–	0	0	0	0	0	0	0	0	–	0	0	0	0	0	1
	6-84	.37	1	0	0	–	1	0	0	1	0	0	0	0	–	0	0	0	0	0	0
	F		0	2	56	0	5	0	4	4	1	7	8	2	1	10	7	7	8	1	11
	Σ/N		1/43	0/43	18/42	3/8	5/43	0/43	4/43	5/43	2/43	0/43	5/43	0/20	4/22	3/43	0/42	1/43	4/43	4/42	12/43
	%		2	0	43	38	12	0	9	12	5	0	12	0	18	5	0	2	9	[illegible]	28

FIGURE 5-14. RAW DATA SHEET - SAMPLE F, MANUAL EDDY CURRENT BOLT HOLE SCANS (Continued)

	Flaw ID	Flaw Size	TECHNICIAN ID																			
			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	302	13-	130	1312	313	319	132-	1402	1502	16E1	16E2U	16E3	16E4	16E5	16E-
	6-66	.015	0	0	1	1	0	0	0	0	0	0	0	0	1	0	-	1	1	0	0	0
*	6-67	.015	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	1	0	0	0	0
*	6-77	.015	0	0	0	0	0	0	0	0	0	1	0	0	0	0		0		0	0	0
*	1-14	.03	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0
	5-26	.03	0	0	0	0	0	0	0	0	1	1	0	0	0	0		1	0	0	0	0
	5-68	.03	1	0	1	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	1
	5-81	.03	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	0		0	0	1
	5-82	.03	0	0	0	1	0	0	0	1	0	0	0	0	0	0		0		0	0	0
*	5-84	.03	0	0	0	0	0	0	0	0	1	0	0	0	0	0		0		0	0	1
	6-70	.03	0	0	0	0	0	0	0	0	0	1	1	0	0	0		0		0	0	0
	6-72	.03	1	0	0	1	0	1	0	0	0	1	0	0	1	0		1	0	0	0	1
	1-15	.04	0	0	0	0	0	0	1	0	1	0	1	0	1	0	0	0	-	0	0	0
*	2-8	.04	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
*	2-14	.04	0	0	0	0	-	0	0	0	0	0	1	0	1	1	1	0	0	0	0	1
*	B1-18	.04	0	0	0	1	1	0	0	0	0	0	1	0	0	0	-	-	-	0	0	0
	1-71	.05	1	1	1	1	0	0	0	0	0	1	1	0	1	0	0	0		1	1	0
	1-73	.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0	0	0
*	5-65	.05	0	1	0	0	0	0	0	0	0	0	1	0	1	0	-	1	0	0	0	1
	6-15	.05	0	0	0	0	0	0	0	0	0	0	0	0	1	0		0	-	0	0	0
	6-65	.05	0	1	1	0	0	0	0	0	0	0	0	0	1	0	-	1	1	0	0	0
	1-11	.06	1	1	1	1	0	0	0	0	0	0	0	0	1	0	0	0	1	0	1	1
	1-12	.06	1	1	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	2-26	.06	0	0	0	1	0	0	0	1	0	0	1	0	0	0	0	0	-	0	0	1
	2-86	.06	0	0	0	1	0	0	0	0	0	0	1	0	1	0	0	0	-	0	0	0
*	B1-21	.06	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0	-	0	0	0
	6-76	.06	0	0	0	1	0	0	0	1	0	0	0	0	0	0	-	0	-	0	0	0
	1-9	.07	1	1	0	1	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0
	1-24	.07	1	1	0	0	0	0	0	1	0	1	0	0	1	0	1	0	1	0	0	0
	1-66	.07	1	1	1	1	0	0	0	0	0	1	0	0	1	0	1	0	0	0	0	1
	A1-22	.08	0	1	0	0	0	1	1	0	0	1	0	1	0	0	1	1	-	1	1	1
	6-71	.09	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0	-	0	0	0
	1-79	.10	1	1	1	1	0	0	0	0	0	0	1	0	1	0	1	0	0	0	0	0
	2-20	.10	0	1	1	1	1	0	0	1	0	0	0	0	0	0	0	1	-	0	0	1
	2-18	.11	0	1	0	1	1	0	0	1	1	0	0	0	1	0	0	1	-	0	1	1
	5-10	.11	1	1	1	1	0	1	1	0	1	0	0	0	1	0	-	1	0	0	0	1
	A1-21	.12	0	1	1	1	0	1	0	0	0	0	0	0	0	0	1	1	-	1	1	1
	2-72	.13	0	1	0	1	0	0	0	0	0	0	0	0	1	0	0	0	-	0	0	0
	1-23	.15	1	1	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
	2-24	.17	1	1	1	1	0	1	0	0	0	0	1	0	0	0	1	0	0	0	0	0
	1-69	.18	1	1	1	0	0	1	0	0	0	0	0	0	1	0	1	0	0	0	0	0
	A1-1	.185	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0	0	0
	6-73	.23	1	1	1	1	0	1	0	0	1	1	0	0	1	0	-	0	1	0	1	1
	6-84	.37	1	1	1	1	1	1	0	0	1	0	0	0	1	0	-	0	1	1	1	1
	F		6	8	14	27	1	8	10	5	7	27	27	3	19	5	6	11	3	2	7	16
	Σ/N		15/43	22/43	16/43	22/43	4/42	9/42	4/43	6/43	8/43	11/43	11/45	1/43	19/43	1/43	9/23	10/42	7/20	4/45	8/43	15/43
	%		35	51	37	51	10	21	9	14	19	26	24	2	44	2	39	24	35	9	19	35

FIGURE 5-14. RAW DATA SHEET - SAMPLE F, MANUAL EDDY CURRENT BOLT HOLE SCANS (Continued)

	Flaw ID	Flaw Size	TECHNICIAN ID 1703	1804	1806	1810	1811	1813	1819	1820	2001	2002	2003	2005	2008	2010	2011	2011R	2012/20	2014	2015	2205	Σ/N	%
	6-66	.015	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	–	20/77	26.0
*	6-62	.015	0	0	0	0	0	0	0	0	0	1	0	1	0	0	1	0	1	0	1	–	16/77	20.8
*	6-77	.015	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	1	0	0	0	–	7/76	9.2
*	1-14	.03	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	11/77	14.3
	5-26	.03	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	–	7/74	9.5
	5-68	.03	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	–	8/77	10.4
	5-81	.03	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1	–	8/75	10.7
	5-82	.04	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	–	12/75	16.0
*	5-84	.05	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	1	0	1	0	–	10/75	13.3
	6-70	.03	1	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	–	11/76	14.5
	6-72	.03	0	0	0	0	1	1	0	0	1	0	0	0	0	0	0	1	0	1	0	–	18/77	23.4
	1-15	.04	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	0	0	0	9/76	11.8
*	2-8	.04	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	3/79	3.8
*	2-14	.04	0	0	[illegible]	0	1	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0	13/79	16.5
†	B1-10	.04	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	–	12/72	16.7
	1-31	.05	0	0	0	0	0	1	0	0	1	0	1	0	0	0	0	1	0	1	0	0	18/76	23.7
	1-23	.05	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	1	0	1	1	0	8/76	10.5
*	5-65	.05	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1	0	–	14/76	18.4
	6-75	.05	0	0	0	1	0	0	0	0	1	0	1	1	0	0	0	1	0	0	1	–	12/74	16.2
	6-65	.05	1	0	0	0	0	0	0	0	0	1	0	1	0	1	0	0	0	1	0	–	19/77	24.7
	1-11	.06	1	1	0	0	0	0	0	0	1	0	1	1	0	1	0	0	0	1	0	0	18/78	23.1
	1-12	.06	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	14/78	17.9
	2-2	.06	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	12/78	15.4
	2-86	.06	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	6/78	7.7
†	B1-21	.06	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	–	3/73	4.1
	6-76	.06	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	1	0	1	0		13/75	17.3
	1-9	.07	0	0	0	0	0	0	0	0	1	0	1	1	0	1	0	0	0	1	0	0	15/78	19.2
	1-24	.07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	11/77	14.3
	1-66	.07	0	1	0	0	1	1	0	0	0	0	0	1	1	1	0	0	1	0	0	0	23/77	29.9
	A1-22	.08	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	21/75	28.0
	6-31	.09	0	0	0	0	0	1	0	0	1	0	1	1	0	0	0	1	0	0	0	–	14/75	18.7
	1-74	.10	1	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	1	0	0	17/77	22.1
	2-20	.10	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	20/78	25.6
	2-18	.11	1	0	1	1	0	0	1	0	0	0	1	0	0	0	0	0	0	1	0	1	22/78	28.2
	5-10	.11	0	1	0	0	0	1	1	0	1	0	1	1	0	0	0	0	1	1	0		23/77	29.9
	A1-21	.12	0	1	0	0	0	0	1	0	1	1	1	0	1	1	0	0	0	1	0	0	27/75	36.0
	2-12	.13	0	0	0	0	0	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0	11/78	14.1
	1-23	.15	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	0	0	13/77	16.9
	2-24	.17	0	0	1	0	0	0	0	0	1	0	1	0	0	0	0	0	0	1	0	0	16/80	20.0
	1-69	.18	1	1	0	0	0	0	0	0	0	1	0	1	1	1	0	0	1	1	0	0	27/78	34.6
	A1-1	.185	0	1	0	0	0	0	1	0	1	1	1	0	0	1	0	0	0	1	0	0	14/77	18.2
	6-73	.23	1	1	1	0	0	0	0	1	0	0	0	1	0	0	0	1	0	1	1	–	30/77	39.0
	6-84	.37	1	1	1	1	0	1	0	1	0	0	0	1	0	0	0	1	1	0	0	–	27/77	35.1
	F		30	6	11	2	3	5	21	10	12	15	12	107	22	15	4	69	24	87	34	1		
	Σ/N		12/43	11/43	10/43	3/43	3/43	6/43	10/43	3/43	12/43	6/43	15/43	28/43	3/43	8/43	1/43	14/43	13/43	24/43	8/43	1/23		
	%		28	26	23	7	7	14	23	7	28	14	35	65	7	19	2	33	28	56	19	4		

FIGURE 5-14. RAW DATA SHEET - SAMPLE F, MANUAL EDDY CURRENT BOLT HOLE SCANS (Continued)

	Flaw ID	Flaw Size	1102	1115	1117	1301	1319	1402	16E7	16E2U	1803	1810	2002	2012/2	2015	2203	Σ/n	%
	6-66	.015	0	0	0	0	1	0	0	0	0	0	0	1		1	3/13	23.1
*	6-67	.015	0	0	0	0	1	0	1	0	0	0	0	1		1	4/13	30.8
*	6-77	.015	0	0	0	0	0	0	0	0	0	1	0	0		1	2/13	15.4
*	1-14	.03	1	1	0	0	0	1	-	0	0	1	1	0		1	6/12	50.0
	5-26	.03	0	0	0	0	0	0	0	0	0	0	0	0		1	1/13	7.7
	5-68	.03	0	0	0	0	0	0	0	0	0	0	1	0		1	2/13	15.4
	5-81	.03	0	0	0	0	0	0	0	0	0	1	0	0		1	2/13	15.4
	5-82	.03	0	0	0	0	0	1	0	0	1	1	0	0		1	3/13	23.1
*	5-84	.03	0	0	0	0	0	0	0	0	0	1	0	0		1	2/13	15.4
	6-70	.03	0	0	0	0	1	0	1	0	0	0	0	1		1	4/13	30.8
	6-72	.03	0	0	0	0	0	0	0	0	0	0	0	0		1	1/13	7.7
	1-15	.04	0	0	0	1	0	1	-	1	0	0	0	0		0	3/12	25.0
*	2-8	.04	0	0	0	0	0	1	-	0	0	0	0	0		1	2/12	16.7
*	2-14	.04	0	0	0	0	0	0	-	0	0	0	1	1		0	2/12	16.7
*	81-18	.04	0	0	0	0	0	0	-	0		0	0	1	1	1	3/13	23.1
	1-71	.05	1	1	0	1	1	1	-	1	1	0	0	0		0	7/12	58.3
	1-73	.05	0	0	0	0	1	0	-	0	0	1	0	0		0	2/12	16.7
*	5-65	.05	0	0	0	1	1	0	1	1	0	0	0	1		1	6/13	46.2
	6-15	.05	0	0	0	0	0	0	0	1	0	1	0	0		1	3/13	23.1
	6-65	.05	0	0	0	0	1	0	1	0	0	0	0	1		1	4/13	30.8
	1-11	.06	1	1	0	1	0	1	-	1	1	0	0	1		1	8/12	66.7
	1-12	.06	1	1	0	1	0	1	-	1	1	0	0	1		1	8/12	66.7
	2-26	.06	0	0	0	1	0	0	-	1	0	1	0	0		1	4/12	33.3
	2-86	.06	0	0	0	1	0	1	-	0	0	0	0	0		1	3/12	25.0
*	81-21	.06	0	0	0	0	0	0	-	0	0	1	0	0		1	2/12	16.7
	6-76	.06	0	0	0	0	1	1	0	1	0	0	0	0		1	4/13	30.8
	1-9	.07	1	1	1	1	0	0	-	0	0	0	0	1		1	6/12	50.0
	1-24	.07	1	1	1	1	0	1	-	1	0	1	0	0		1	8/12	66.7
	1-66	.07	1	1	0	1	1	1	-	1	0	1	0	1		1	9/12	75.0
	A1-22	.08	1	0	0	0	1	1	-	1	0	1	1	0		0	6/12	50.0
	6-71	.09	0	0	0	1	0	0	0	0	0	1	0	0		1	3/13	23.1
	1-79	.10	1	1	1	1	1	1	-	1	1	1	0	1		1	11/12	91.7
	2-20	.10	1	1	1	1	1	1	-	1	0	1	0	0		1	9/12	75.0
	2-18	.11	1	1	1	1	0	1	-	1	0	1	0	0		1	8/12	66.7
	5-10	.11	1	1	1	1	1	0	1	1	1	0	1	1		1	11/13	84.6
	A1-21	.12	1	0	1	1	0	1	-	1	1	1	1	0		0	8/12	66.7
	2-72	.13	1	1	0	1	0	1	-	1	0	1	0	0		1	7/12	58.3
	1-23	.15	1	1	1	1	1	1	-	1	1	1	0	1		1	11/12	91.7
	2-24	.17	1	1	1	1	1	1	-	1	1	0	0	0		1	9/12	75.0
	1-69	.18	1	1	1	1	1	1	-	1	0	1	1	1		1	11/12	91.7
	A1-1	.185	1	0	0	1	1	1	-	0	0	0	0	0		0	4/12	33.3
	6-73	.23	1	1	1	1	1	0	0	1	1	0	0	0		1	8/13	61.5
	6-84	.37	1	1	1	1	1	0	0	1	1	0	0	0		1	8/13	61.5
	F		7	7	11	17	27	20	14	11	3	63	21	69	17	128		
	Σ/N		20/43	17/43	12/43	23/43	19/43	21/43	5/18	22/43	12/43	20/43	7/43	15/43	1/1	36/43		
	%		47	40	28	53	44	49	28	51	28	47	16	35	100	84		

FIGURE 5-15. RAW DATA SHEET - SAMPLE F, AUTOMATIC EDDY CURRENT BOLT HOLE SCANS

Flaw ID	Flaw Size	TECHNICIAN ID																						
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1001	1027	[illegible]	[illegible]	1108	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				
6-66	.015	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0				
* 6-67	.015	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0								
* 6-77	.015	0	0	0	0	0	0	0	-	0	0	0	0	0	0	0								
* 1-14	.03	0	0	0	0	1	0	0		0	0	0	0	0	0	0								
5-26	.03	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0								
5-68	.03	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0								
5-81	.03	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0								
5-82	.03	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0								
* 5-84	.03	0	0	0	0	0	0	0	0		0	0	0	0	0	0								
6-70	.03	0	0	0	0	0	0	0	-	0	0	0	0	0	0	0								
6-72	.03	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0								
1-15	.04	0	0	0	0	0	0	0	-	0	0	0	0	0	0	0								
* 2-8	.04	0	0	0	0	0	0	0	0	0	-	0	0	0	0	0								
* 2-14	.04	0	0	0	0	0	0	0		0	0	0	0	0	0	0								
* B1-18	.04	0			0	1	0	1	-	0	0	0	0	0	0	0				1				
1-21	.05	0	0	1	0	1	0	0	-	0	0	0	0	0	0	0								
1-23	.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0								
* 5-65	.05	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0								
6-15	.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0								
6-65	.05	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0								
1-11	.06	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0								
1-12	.06	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0								
2-26	.06	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0								
2-86	.06	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0								
* B1-21	.06	0	0	0	0	0	0	1	-	0	0	0	0	0	0	0								
6-76	.06	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0								
1-9	.07	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0								
1-24	.07	0	0	0	0	1	0	0	-	0	0	0	0	0	0	-								
1-66	.07	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0			0				
A1-22	.08	1	1	1	1	0	0	0	-	1	1	0	0	0	0	0	1		1	1				
6-71	.09	0	0	0	0	0	0	0	-	0	0	0	0	0	0	0	0			0				
1-79	.10	0	0	0	0	0	0	1	-	0	0	0	0	0	0	-								
2-20	.10	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0			1					
2-18	.11	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0								
5-10	.11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0								
A1-21	.12	1	1	0	1	0	0	1	-	1	1	1	1	1	1	1	1	0	1	1				
2-32	.13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0				
1-23	.15	0	0	0	0	0	0	1	-	0	0	0	0	0	0	-	0			1				
2-24	.17	0	0	0	0	0	0	1	-	0	0	0	0	0	0	0	0		0					
1-69	.18	0	0	1	0	1	0	1	-	0	0	0	0	0	0	0	1							
A1-1	.185	0	0	0	0	1	0	0	-	0	0	1	1	1	0	0	1							
6-73	.23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0							
6-84	.37	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0								
F		0	0	6	0	26	8	14	1	1	9	6	2	2	4		1	2	23	2				
E/N		2/43	3/43	6/43	2/43	8/42	5/43	3/43	1/26	3/43	5/42	3/43	3/43	3/45	3/40	1/40	4/40	0/43	3/43	4/43				
%		5	5	14	5	19	12	16	4	7	12	5	7	7	5	3	9	0	7	9				

FIGURE 5-16. RAW DATA SHEET - SAMPLE F, ULTRASONIC SHEAR WAVE SCANS

	Flaw ID	Flaw Size	1641	1614	1615	6E24	1802	1808	1818	Σ/N	%
	6-66	.015	0	0	0	0	0	0	0	1/26	3.8
*	6-67	.015	1	0	0	0	0	0	0	2/26	7.7
**	6-77	.015		0	0	0	0	0	0	0/25	0
*	1-14	.02	0	0	0	0	0	0	0	1/25	4.0
	5-26	.03	1		1	0	0	0	0	2/26	7.7
	5-68	.03	1	0	0	0	0	0	1	2/26	7.7
	5-81	.03		0	0	0	0	0	0	0/26	0
	5-82	.03		0	0	0	0	0	1	2/26	7.7
*	5-84	.03		0	0	0	0	0	0	0/26	0
	6-20	.03		0	1	0	0	0	0	1/25	4.0
	6-22	.03		0		0	0	0	0	0/26	0
	1-15	.04	0	0	1	0	0	0	0	1/25	4.0
*	2-8	.04	1	0	0	0	1	0	0	2/25	8.0
*	2-14	.04	1	0	0	0	0	0	0	1/25	4.0
*	B1-18	.04	0	0	0	0	-	0	0	3/24	12.5
	1-21	.05	0	0	1	0	0	0	0	3/25	12.0
	1-23	.05	1	0	1	0	0	0	0	2/26	7.7
*	5-65	.05	1	0	0	0	0	0	1	3/26	11.5
	6-15	.05	0	1	0	0	0	0	0	1/26	3.8
	6-65	.05	0	0	0	0	0	0	0	2/26	7.7
	1-11	.06	0	0	0	0	0	0	0	1/26	3.8
	1-12	.06	0	0	1	0	0	0	0	3/26	11.5
	2-26	.06	0	0	0	0	0	0	0	0/26	0
	2-86	.06	0	0	1	0	0	0	0	2/26	7.7
*	B1-21	.06	1	0	1	0	0	0	1	4/25	16.0
	6-26	.06		0	0	0	0	0	0	0/26	0
	1-9	.07		0	1		0	0	0	2/26	7.7
	1-24	.07	1	0	0	0	0	0	0	2/24	8.3
	1-66	.07	0	0	0	0	0	0	0	1/26	3.8
	A1-22	.08	1	0	0	1	1	0	1	13/25	52.0
	6-71	.09			0	0	0	0	0	1/25	4.0
	1-29	.10	1			0	0	0	0	2/24	8.3
	2-20	.10			0	0	0	0	0	2/26	7.7
	2-18	.11			1	0	0	0	0	3/26	11.5
	5-10	.11	0	0	0	0	0	0	0	0/26	0
	A1-21	.12	1	0	0	1	1	0	1	18/25	72.0
	2-32	.13	1				0	0	0	1/26	3.8
	1-23	.15	1	0		0	0	0	0	3/24	12.5
	2-24	.17		0		0	0	0	0	1/25	4.0
	1-69	.18	1	0	0	0	0	0	0	5/25	20.0
	A1-1	.185	1	0	0	1	0	0	0	7/25	28.0
	6-73	.23	0	1	0	0	0	0	0	1/26	3.8
	6-84	.37		0	0	0	0	0	0	3/26	11.5
	F		45	2	13	1	5	9	54		
	Σ/N		16/43	3/43	10/43	3/43	3/42	0/43	6/43		
	%		37	7	23	7	7	0	14		

FIGURE 5-16. RAW DATA SHEET - SAMPLE E, ULTRASONIC SHEAR WAVE SCANS (Continued)

FACILITY EVALUATION

DATE ____________

1. Setup Location ______________________________

2. Ambient Conditions ______________________________

3. Light and Noise Level ______________________________

4. Ancillary Equipment Evaluation ______________________________

5. Description of Inspection Area ______________________________

6. NCO In Charge: Communications or Discussions ______________________________

FIGURE 5-17

DAILY LOG

DATE ______

TECHNICIAN NO.	SPECIMENS INSPECTED
______	______
______	______
______	______
______	______
______	______
______	______

WEATHER ______

SPECIAL CONDITIONS ______

______

______

INSTRUMENTATION OPERATIONS ______

______

______

TECHNICIAN EVALUATION

1.	7.
2.	8.
3.	9.
4.	10.
5.	11.
6.	12.

COMMENTS ______

FIGURE 5-18

TECHNICIAN PROFILE FORM

1. Assigned A/F Identification No. ____________________

2. Date ______________

3. Job Title/AFSC ________________________________

4. Education:

   Grade School-High School: No. of Years ________ Graduate ________

   College: No. Years __________ Graduate ________ Major __________

NDI Training	Dates (Mo.-Yr.)	No. Hours

5. NDI Experience:

   (A) How Long have you been in NDI? ______ Yrs. ________ Mths.

   (B) How many inspections per month do you perform on Engine Parts (E) and Aircraft Structure (A/C)?

   Ultrasonic: (E)_____ (A/C)_____; Eddy Current (Surface Probe): (E)_____ (A/C)_____; Eddy Current (Bolt Hole Probe-Manual): (E)_____ (A/C)_____; Eddy Current (Bolt Hole Probe-Automatic): (E)_____ (A/C)_____; Penetrant: (E)_____ (A/C)_____; X-ray: (E)_____ (A/C)_____

6. Job History (Start with most recent job and work backward - Estimate dates if actual dates unknown)

   (A) From ________ To ________ Job Title ____________________________

   ____
   (Brief Description)

FIGURE 5-19

(B) From ____________ To ____________ Job Title ______________________________

____
(Brief Description)
____

____

(C) From ____________ To ____________ Job Title ______________________________

____
(Brief Description)
____

____

(D) From ____________ To ____________ Job Title ______________________________

____
(Brief Description)
____

____

(E) From ____________ To ____________ Job Title ______________________________

____
(Brief Description)
____

____

7. Physical Data

Height __________ Weight __________ Age __________ Sex M ___ F ___

Married __________ Single __________

Wear Glasses? ____________________

Physical Limitations ______________

____
(Describe)
____

FIGURE 5-19 (Continued)

EQUIPMENT PERFORMANCE CHECK
X-RAY

(1) Air Force Base

____

(2) Stepwedge No.	(3) Date	(4) Lockheed Rep/AF NDI Technical ID No.

(5) Equipment/Material Used:

X-ray Equip. Mfg. ________ Model ________ Serial No. ________

Film Mfg. ________ Type ________ Backing ________

Developer Test Strip Mfg. ________ Type ________

Chemicals	Mfg.	Type
Developer	________	________
Stop Bath	________	________
Fixer	________	________
Hypo Eliminator	________	________
Wetting Agent	________	________

(6) Techniques Parameters:

FFD ________ KV ________ MA ________ Time ________

Process: Hand ________ Automatic ________

(7) Processing Information:

Hand

Developer Time ____ Temp ____

Stop Bath Time ____ Temp ____

Fixer Time ____ Temp ____

Hypo Eliminator Type ________

Wash Time ____ Temp ____

Wetting Agent Type ________

Automatic

Mfg. ________ Model ________

Serial No. ________

Time ________ Temp. ________

FIGURE 5-20

(8) Instructions:

( ) (a) X-ray Stepwedge using Two Kodak Type M Film - One Exposure

( ) (b) Repeat (a) for Twice the Exposure Time

( ) (c) Develop the Two No. 2* Films at the A/F site

( ) (d) Develop one test strip at the A/F site

( ) (e) Return the two undeveloped No. 1* films to Lockheed for developing

* No. 1 film next to Stepwedge; No. 2 film double loaded

(9) Comments:

FIGURE 5-20 (Continued)

EQUIPMENT PERFORMANCE CHECK
FLUORESCENT PENETRANT

(1) Air Force Base

____

(2) Date ______________

(3) Lockheed Rep/AF NDI Technician ID No. ______________

(4) Equipment/Materials Used: TYPE__________ GROUP__________

Material	Manufacturer	Commercial Designation or Trade Name
Penetrant		
Developer		
Cleaner		

(5) Method of Application:

____

(6) Dwell Times:

Material	Time
Penetrant	
Developer	

(7) Comments:

____

____

____

____

____

____

____

FIGURE 5-21

EQUIPMENT PERFORMANCE CHECK EDDY CURRENT		
(1) Air Force Base ______________________		
(2) Calibration Std. ID No.	(3) Date	(4) Lockheed Rep/AF NDI Technician ID No.
(5) Equipment/Materials Used: ( ) Surface Probe ( ) Bolt Hole Probe ( ) Automatic Bolt Hole Probe Instrument Mfg. ________ Model ________ Serial No. ________ Transducer Mfg. ________ Model ________ Stock No. ________		
(6) Equipment Settings: Balance ________ Lift-off/Freq. ________ Range ________ (For Automatic) Strip Chart Speed ________ Probe Rotation Speed ________ Probe Advance for Revolution ________		
(7) No. Microvolts Deflection using Calibration Std. ________		
(8) Comments:		

FIGURE 5-22

EQUIPMENT PERFORMANCE CHECK ULTRASONIC

(1) Air Force Base

(2) Date

(3) Lockheed Rep/Inspector ID No. (A/F)

(4) Equipment/Material Used:

Mfg. ____________ Model ____________ Serial No. ____________

Transducer (Freq., Angle, Size, Mfg. and Serial No. ____________

____________ ____________

Type & Length of Cable ____________

(5) Inspection Procedure Identification

(6) Equipment Settings:

Horizontal

Coarse Sweep (Range/Multiplier ____________ Coarse Gain (Amplif) ____________

Fine Sweep (Vernier ____________ Fine Gain (Vernier) ____________

Delay ____________ Zero Suppression (Reject) ____________

Pulse Length ____________

Pulse Tuning ____________

Frequency ____________

(7) Linearity:

Horizontal, Inter-Echo Spacing 1-2 ____________ % Full Scale

Lockheed Block 2-3 ____________

Vertical Echo Height No. 3 ____________ (13) % Full Scale

ASTM Blocks No. 5 ____________ (35)*

No. 8 ____________ (90)

*Initial Gain Setting

FIGURE 5-23

EQUIPMENT PERFORMANCE CHECK (continued) - ULTRASONIC

(8) Transducer (Angle Beam): Make and Serial No.

Beam Exit Error ______________ Inches

Beam Angle ______________ Degrees

(9) Comments:

____

____

____

____

____

____

____

FIGURE 5-23 (Continued)

NONDESTRUCTIVE INSPECTION DATA
ULTRASONIC

(1) Air Force Base ____________________

(2) Assigned AF NDI Technician ID No.	(3) Date	(4) Sample Identification

(5) Equipment/Material Used:

Ultrasonic Inst. Mfg. __________ Model ______ Serial No. ______

__________ Model ______ Serial No. ______

Transducer Mfg. __________ Model ______ Serial No. ______

Freq. ______ Angle ______ Size ______ Couplant ______

(6) Inspection Procedure Identification: ____________________

____

Calibration Std. ID No. ____________________

(7) Equipment Calibration Settings:

Sweep __________ Pulse Length __________ Frequency __________

__________ Reject __________ Test Mode Pulse Echo

__________ Sensitivity __________ Damping __________

Other (Record under Comments)

(8) Inspection Start/Stop Times (Date if after Item 3 Date)

Start	Stop	Start	Stop

(9) Inspector Comments (Equipment Adjustments, Inspection Procedure Variations, Other Comments)

____

____

____

FIGURE 5-24

NONDESTRUCTIVE INSPECTION DATA FLUORESCENT PENETRANT		
(1) Air Force Base ______________________________		
(2) Assigned A/F NDI Technician ID No.	(3) Date	(4) Sample No.
(5) Equipment/Material Used: Penetrant Type __________ Group __________ Material — Manufacturer — Commercial Designation or Trade Name Penetrant __________ __________ Developer __________ __________ Cleaner __________ __________		
(6) Inspection Procedure Identification: __________ __________		
(7) Method of Application: __________ Dwell Times: Penetrant __________ Developer __________		
(8) Inspection Start/Stop Times (Date if after Item 3 date): Start — Stop — Start — Stop _____ _____ _____ _____ _____ _____ _____ _____ _____ _____ _____ _____		

FIGURE 5-25

NONDESTRUCTIVE INSPECTION DATA - FLUORESCENT PENETRANT

(9) Inspector's Comments: (Material/Equipment Adjustments, Inspection Procedure Variations, Other Comments)

FIGURE 5-25 (Continued)

NONDESTRUCTIVE INSPECTION DATA
RADIOGRAPHIC (X-RAY)

(1) Air Force Base

____

(2) Assigned A/F NDI Technician ID No.	(3) Date	(4) Sample Identification

(5) Equipment/Materials Used:

X-Ray Equip. Mfg. ____________ Model ____________ Serial No. ________

Film Mfg. ________ Loading: ( ) Single ( ) Double

Film Type: No. 1 (next to sample) _____; No. 2 ________ Pack Size ________

Screens ____________ Backing ____________

(6) Inspection Procedure Identification ______________________

(7) Technique Parameters:

FFD/Tube to Aiming Point ________ KV ________ MA ______ Time ______ Min.

Automatic Process:

Developer Temp ______

Hand Process:

Developer Time ______ Temp ______

Stop Bath Time ______ Temp ______

Fixer Time ______ Temp ______

Hypo Eliminator Type ________

Wash Time ______ Temp ______

Wetting Agent Type ________

Density Range in areas to be inspected ______________________

(8) Inspection Start/Stop Times (Date if after Item 3 Date)

Start	Stop	Start	Stop
________	________	________	________
________	________	________	________
________	________	________	________

FIGURE 5-26

(9) Inspector Comments: (Equipment Adjustments, Inspection Procedure Variation, Other Comments)

FIGURE 5-26 (Continued)

NONDESTRUCTIVE INSPECTION DATA
EDDY CURRENT (SURFACE PROBE)

(1) Air Force Base

(2) Assigned A/F NDI Technician ID No.

(3) Date

(4) Sample Ident. & Position
( ) Sample A
( ) Sample B, Overhead
( ) Sample B, Below

(5) Equipment/Material Used:

Eddy Current Inst. Mfg.________ Model________ Stock or Serial No.________

Probe Mfg.________ Model________ Stock No.________

(If shoe, holder, jig or probe fixture is used, describe under "Comments"

(6) Inspection Procedure Identification:________

________ Calibration Std. ID No.________

(7) Equipment Calibration Settings:

Balance________ Lift-off/Freq.________ Range________

(8) Inspection Start/Stop Times (Date if after Item 3 Date)

Start	Stop	Start	Stop

(9) Inspector's Comments: (Equipment Adjustment, Inspection Procedure Variation, Other Comments)

FIGURE 5-27

NONDESTRUCTIVE INSPECTION DATA
EDDY CURRENT (BOLT HOLE MANUAL)

(1) Air Force Base ________________________________

(2) Assigned A/F NDI Technician ID No.	(3) Date	(4) Sample Identification

(5) Equipment/Material Used:

Eddy Current Inst. Mfg. ____________ Model ________ Stock or Serial No. ______

Probe Mfg. ____________ Model ________ Stock No. ______

(6) Inspection Procedure Identificction: ________________

________________ Calibration Std. ID No. ________________

(7) Equipment Calibration Settings:

Balance ____________ Lift-off/Freq. ____________ Range ____________

(8) Inspection Start/Stop Times (Date if after Item 3 Date):

Start	Stop	Start	Stop

(9) Inspector's Comments: (Equipment Adjustments, Inspection Procedure Variations, Other Comments)

FIGURE 5 28

NONDESTRUCTIVE INSPECTION DATA
EDDY CURRENT (BOLT HOLE AUTOMATIC)

(1) Air Force Base ______________________________

(2) Assigned A/F NDI Technician ID No. | (3) Date | (4) Sample Identification

(5) Equipment/Materials Used:

Eddy Current Inst. Mfg. ____________ Model ____________ Stock or Serial No. ________

Probe Mfg. ____________ Model ____________ Stock No. ________

(6) Inspection Procedure Identification: ______________________________

______________________________ Calibration Std. ID No. ____________

(7) Equipment Calibration Settings:

Balance ____________ Lift-off/Freq. ____________ Range ____________

Strip Chart Speed ____________ Probe Rotation Speed ____________

Probe Advance per Revoltion ____________

(8) Inspection Start/Stop Times (Date if after Item 3 Date)

Start	Stop	Start	Stop

(9) Inspector's Comments: (Equipment Adjustments, Inspection Procedure Variation, Other Comments)

____

____

____

____

____

____

FIGURE 5-29

SECTION VI. PROGRAM ADDITIONS

During the data acquisition phase of the NDI Reliability Program, which lasted for over two years, certain newly-developed NDI equipment and specially-fabricated test specimens were added to the program. Automatic eddy current bolt hole inspection was added in December of 1976 so that comparisons could be made between the newer automatic techniques and the standard hand-held eddy current bolt hole technique. A newly developed ultrasonic rotational surface scanner was also added in December of 1976 to measure the potential improvement in inspection reliability. Finally, a group of 76 Technician Proficiency Screening Samples recommended by the Steering Committee in January 1977 were added in July of 1977 to determine if a relatively simple small inspection sample could be used to evaluate or predict technician NDI ability on larger more complex structure. The automatic bolt hole technique was applied to program Samples D, E, and F and the ultrasonic instrument was applied to program Sample A. Standard manual ultrasonic and eddy current bolt hole NDI techniques were applied to the screening samples, designated as a new Sample Group G.

AUTOMATIC EDDY CURRENT BOLT HOLE INSPECTIONS

Two Gulton FD-100 automatic eddy current bolt hole inspection instruments were obtained for use in evaluating the automatic bolt hole technique during the on-going NDI Reliability Program. The Gulton unit (see Figure 6-1) is composed of the following major assemblies:

A. Motorized Scanner
B. Eddy Current Amplifier
C. Signal Conditioning Circuitry
D. Analog Recorder
E. Scanning Probes and Mounting Hardware

The motorized scanner rotates an eddy current bolt hole probe at a controllable rate from approximately 10 rpm to 100 rpm. As the probe rotates, it spirals in the forward or reverse directions. Longitudinal probe travel is 0.025" per revolution, or 40 revolutions per inch. Probe travel is controllable and maximum travel is 1-1/2".

During a scan of a fastener hole, the eddy current amplitude output is filtered to enhance the flaw signal as it is transmitted to the analog recorder. As an alternative, the signal can be viewed on an auxillary oscilloscope and then, if flaw indications are seen, the signal can be recorded by the analog recording during another pass of the probe through the hole. The recorded data can be examined to determine flaw length, depth and width.

A procedure document titled "Self Introduction for Automated Eddy Current Scanning System" and an Operational Supplement to the NDI Reliability Program Technical Manual (see Appendix A) were prepared for use in implementing this addition. Calibration standards and two technician practice specimens, as shown in Appendix A, were also prepared.

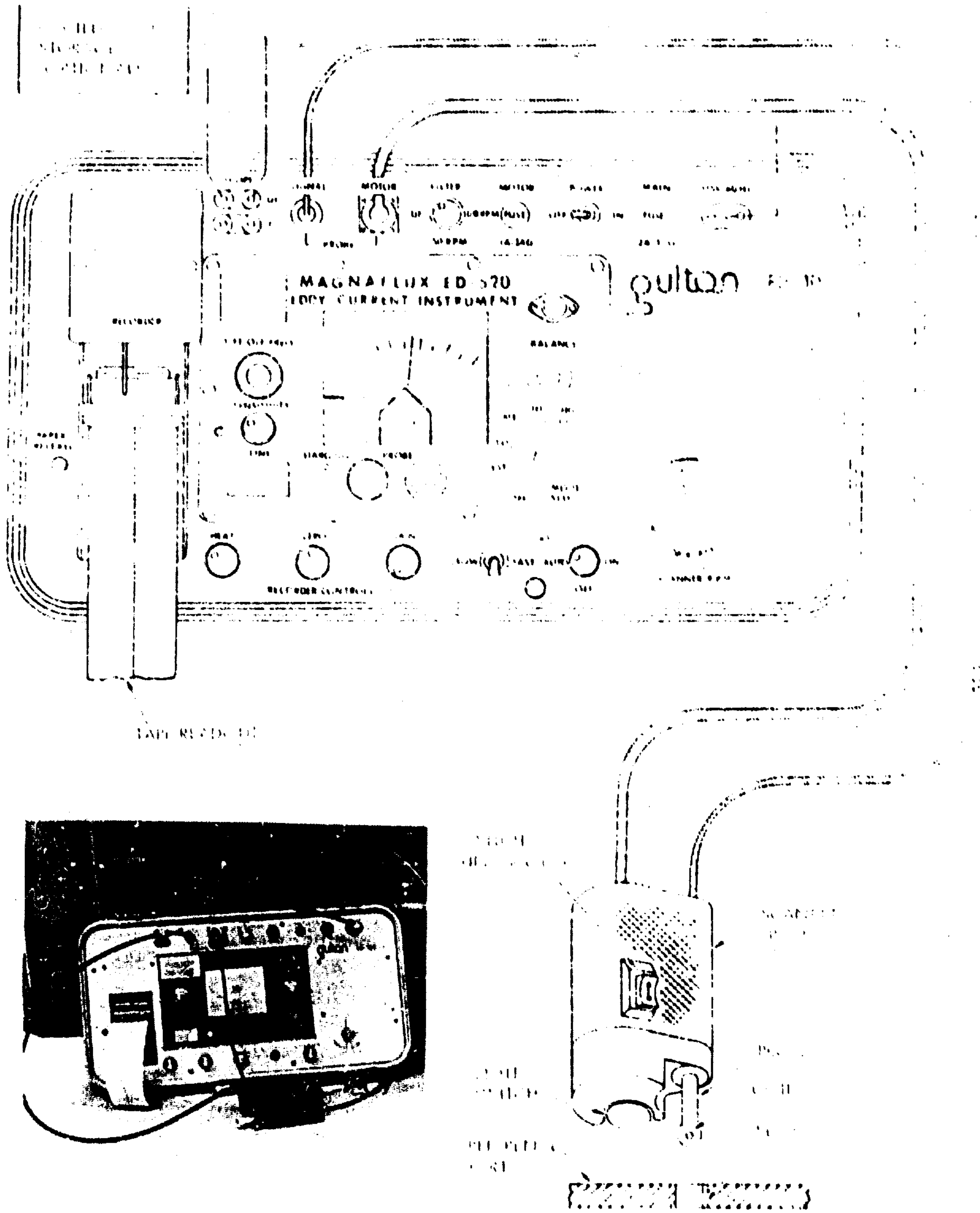


Figure 6-1. The Guiton Automated Eddy Current Scanning System

The two practice samples were test panels that were built up and structurally evaluated in other programs. They were selected for use in this program because of their existing fatigue crack population and similarity to samples already contained in the program. One was a spanwise splice test panel and the other was a center wing cap, riser-to-web test panel. Each was about four feet long and each contained a number of cracked holes. Two standards were prepared for use in the program. One was a spanwise splice standard and the other was a center wing standard. Each had a 0.030 through Elox slot in one bolt hole.

For each hole in the practice specimens that contained a crack, a copy of the recorded analog tape was reproduced and printed in the procedure document, along with an explanation of the recording and an interpretation of the recorded signal. Each technician was allowed to become familiar with the instrument by going through the detailed instrument setup procedures and working with the practice specimens for as long as necessary. It was felt that this documentation and practice period was necessary as most of the installations visited had not yet received the automatic eddy current equipment.

This automatic eddy current part of the program was initiated in December of 1976 at Dover AFB, Delaware. However, some automatic bolt hole inspections had been accomplished previously at McClellan in September and October of 1976 using their own equipment (see Figure 4-3 for bases participating in the various parts of the program).

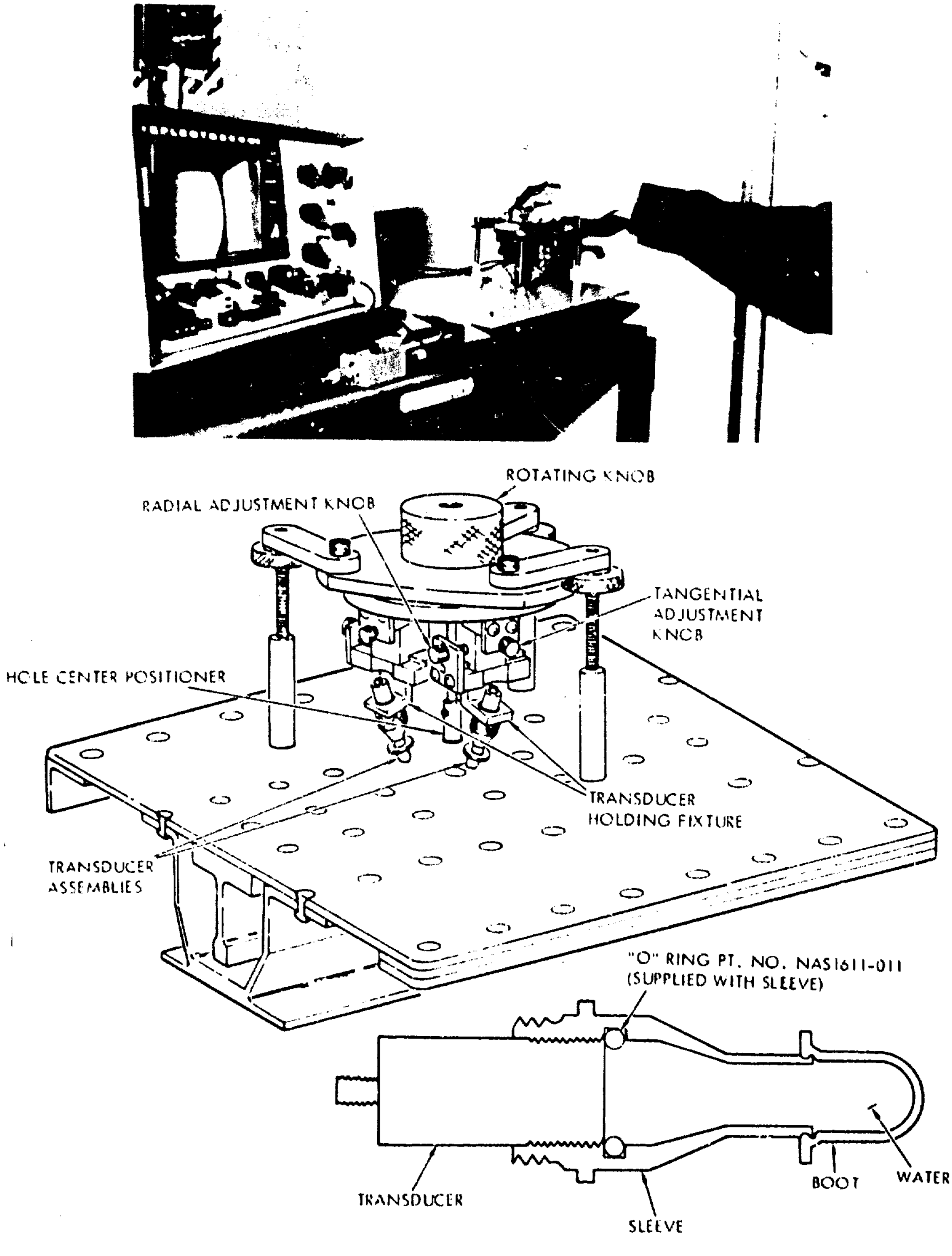
The automatic eddy current bolt hole program was generally well received by the Air Force technicians. Most all had heard of the Gulton unit and were interested in having the opportunity to become familiar with it.

The inspection results acquired with this unit will perhaps improve somewhat as the Air Force technicians become more familiar with the unit, and particularly with the interpretation of the analog data.

ULTRASONIC ROTATIONAL SCANNER INSPECTIONS

A manual adaptation of the AFML/Boeing ultrasonic rotational scanner system was developed at the San Antonio Air Logistics Center for use in the detection of radial cracks around fastener holes (see Figure 6-2). The system consisted of an ultrasonic instrument and rotational scanner assembly that contained two transducers.

The scanner head assembly consisted of (1) three adjustable legs, (2) a centering device for positioning the transducers around the fastener head, (3) an adjustable transducer holder, and (4) a transducer assembly. The transducer holder was adjustable for alignment of the transducer sound beam to the edge (circumference) of the hole. The holder was adjustable in three directions; tangential, radial, and angular. These adjustments allowed the operator to direct a shear wave to the base of the countersink. The tangential adjustment moved the transducer assembly toward and away from the fastener hole. The radial adjustment moved the transducer assembly to the right or left of the fastener hole. The angle was adjustable using a template to set it at the desired angle for sound entry into the part. This adjustment, once set, was fixed and could not be continuously adjusted in order to maximize the signal response.



TRANSDUCER ASSEMBLY

Figure 6-2. Ultrasonic Rotational Scanner

The transducer assembly consisted of a transducer, a transducer sleeve, water, and a flexible boot (see Figure 6-2). The transducer assembly screwed into the transducer holder. A water column, confined by means of the transducer, transducer sleeve and flexible boot transmitted the sound through the rubber boot to the test piece. The instrument utilized with the manual scanner head assembly was an Automation Industries UM 775D with a AG1FM Timer and 10NRF-VDB Pulser/Receiver.

A detailed procedure and an Operational Supplement to the NDI Reliability Program Technical Manual were provided for set-up, calibration, and use with the supplied practice samples and structure Sample A (see Appendix B). A calibration standard and practice samples, as shown in Appendix B, were also provided with the scanner head and ultrasonic instrumentation. Both the standard and practice samples were pieces of C-130 wing box. The standard had one fastener removed and a sawcut made in that fastener hole for calibration purposes. The practice samples were selected for their crack population and all fasteners were left in the installed configuration. Technicians were allowed to become familiar with the instrument and work with the practice samples as long as each felt necessary. After they were familiar with its operation, each was assigned to inspect structure Sample A.

Although the inspection technique worked well, when all adjustments were properly made, much difficulty was encountered by the technician in getting the rotational scanner properly adjusted. Unfortunately, most technicians found the task too difficult and did not progress beyond the practice sample portion of the program, so only four Sample A inspections were completed. Some of the specific problems encountered were as follows:

- Installing water into the transducer-sleeve-boot assembly without trapping air bubbles.

- Adjustment of the holder in the tangential-radial-angular directions for both transducers.

- Proper adjustment of the three legs so that both boots were in proper contact on the entire surface as the scanner head was rotated.

- Boots coming off during inspection.

Those few with patience did get the instrument set up and operational; however, the inspection of structure Sample A took considerably longer with the rotational scanner than by using the standard hand scan technique.

NDI PROFICIENCY SCREENING SAMPLE PROGRAM

This program was designed to determine if it is possible to measure nondestructive inspection capability using small flat panels as testing samples rather than actual built-up aircraft structures. The program consisted of a technical activity in which flat panels, prepared in the laboratory with known defects, were incorporated into the on-going NDI Reliability Program. These panels, along with the typical aircraft structures that already existed in that program, were inspected in depot and field NDI installations. The NDI reliability data collected using

the flat panels have been statistically compared to the data collected for the actual structures to test for significant correlations between the two (see Section XI).

Fabrication of Flat Panels

Seventy-eight specimen blanks nominally two inches by sixteen inches were machined from 0.20 inch thick, bare 7075-T651 aluminum alloy sheet. Each blank was uniquely serialized and, as subsequently described, all blanks ultimately contained ten fastener holes to provide a total of 780 holes. Fatigue cracks were initiated and grown beside a total of 123 holes, and four different nominal crack length intervals were employed; 0.050"-0.100", 0.101"-0.175", 0.176"-0.250", and 0.251"-0.350". Crack length and location were randomly distributed within three different groups as follows: Each blank having a serialization prefix "A" had one cracked hole, each prefix "B" blank had two cracked holes, and each prefix "C" blank had three cracked holes. A fourth group, "D", either had no cracked holes or had electrical-discharge-machined (EDM) flaws for use in calibration.

All blanks were profiled from a single skin quality sheet and serialized on one end using an impression stamp. A drill fixture was fabricated having provision to hold the specimen securely while drilling holes precisely at the desired locations. Use of the fixture expedited the drilling operation as well as assuring likeness of specimens. Each drilling location on the fixture was numbered and each specimen was placed on the fixture with the same orientation with respect to its serialization location. Each hole requiring a crack was then pilot drilled to 7/64-inch diameter while the remaining hole positions were not drilled to prevent the possibility of generating undesired cracks during fatigue cycling.

Beginning with the "A" specimens requiring only one cracked hole, each specimen was mounted on a 75,000-pound capacity MTS closed-loop, electro-hydraulic servo-controlled testing system equipped with hydraulic self-aligning grips.

With the specimen mounted in the testing machine at zero load, a starter flaw was cut on the hole wall. A thru flaw of approximately 0.02-inch in length was introduced so that during final reaming, the starter flaw could be completely removed. A jewelers saw was used to make the cut and care was taken to assure thru-the-thickness symmetry. The natural crack was initiated and grown using a maximum for field stress of 15.0 ksi, a stress ratio (R) of +0.1, and a cyclic frequency of 10 Hz. This selection produced a crack that had the desired visual obscureness with respect to crack path plasticity and did so in a reasonable number of cycles. Crack growth was monitored using a high intensity light and a thirty-power binocular microscope. Cycling was stopped when the crack reached a predetermined length which would provide the desired flaw size after final ream. Accurate records were kept on the number of cycles required for crack initiation and total cycles required to attain each desired length as exhibited in Figure 6-3. The cycle initiation data generally represent cycles required to produce a natural crack approximately 0.010 inch long.

Data acquired from the single flaw specimens were used to establish procedures for the multiple flaw specimens requiring different flaw sizes in the same specimen. For these cases, a starter flaw was first made for the longest desired crack. After a predetermined number of cycles,

All Fatigue Cycling as Follows:

Max Stress	=	15.0 KSI
Stress Ratio (R)	=	+0.1
Frequency	=	10 Hz
Environment	=	Room Air

Specimen Number	Position Number	Cycles to Initiation	Total Cycles
A1	4	4000	23000
A2	1	3500	14000
A3	6	3500	19000
A4	9	4500	24000
A5	6	3000	16900
A6	1	3000	16000
A7	1	4000	16500
A8	9	4000	24000
A9	0	3000	25500
A10	2	4000	23000
A11	9	3000	11000
A12	0	3000	16000
A13	7	3000	21000
A14	3	3000	11000
A15	3	3000	24000
A16	8	3000	13000
A17	6	2500	25000
A18	7	3000	22000
A19	2	3000	11000
A20	0	3000	21000
A21	3	3000	12000
A22	2	3000	23500
A23	4	4000	28000
A24	0	3500	17500
A25	5	4000	21000
A26	2	3500	29000
A27	8	3500	24000
B1	3	3000	19000
	6	3000	16000
B2	3	4000	11000
	4	3000	19000
B3	9	3000	18000
	2	3500	18000

Figure 6-3. NDI Specimen Fatigue History

Specimen Number	Position Number	Cycles to Initiation	Total Cycles
B4	0	3000	12000
	3	3000	19000
B5	7	3000	19000
	9	4000	12000
B6	4	3500	15000
	2	3000	18000
B7	0	5000	13000
	7	3000	23000
B8	1	3000	19000
	3	3000	16000
B9	9	3000	16500
	3	3500	16500
B10	6	4500	18000
	1	3500	22000
B11	4	3000	21000
	8	3000	21000
B12	1	3000	16000
	6	3000	22000
B13	4	3000	20000
	7	3500	23000
B14	2	3000	13000
	0	3000	24000
B15	7	4000	18000
	0	3000	24000
B16	3	3000	25000
	9	3000	19000
B17	6	4000	24000
	0	3000	24000
B18	6	3000	11000
	3	4000	22000
B19	7	3500	10500
	9	3000	18500
B20	3	3000	17000
	1	4000	14000
B21	7	3000	23000
	1	4000	25000
B22	3	3000	24000
	1	3000	18000
B23	6	3500	13000
	4	3000	24000

Figure 6-3. NDI Specimen Fatigue History (Cont'd)

Specimen Number	Position Number	Cycles to Initiation	Total Cycles
B24	2	3000	11000
	9	3000	19000
B25	5	3000	15000
	6	3000	26000
B26	5	3000	15000
	3	3000	15000
B27	0	3000	19000
	2	3500	21000
B28	5	3500	12000
	9	3000	23000
B29	0	3000	11000
	3	3000	14000
B30	6	3000	14000
	0	3000	17000
B31	2	3000	15000
	0	3000	19000
B32	4	3000	20000
	2	3500	23000
B33	0	3500	18000
	7	3500	15000
C1	7	4000	19000
	2	3000	19000
	5	3000	22000
C2	3	3000	15000
	9	3000	22000
	0	3000	15000
C3	6	3000	23000
	2	3500	16000
	5	3000	16000
C4	2	3000	17000
	8	3500	17000
	5	3500	20000
C5	4	3000	25000
	3	3500	22000
	6	3000	16000
C6	1	3500	18000
	3	2000	18000
	5	3500	25000

Figure 6-3. NDI Specimen Fatigue History (Cont'd)

Specimen Number	Position Number	Cycles to Initiation	Total Cycles
C7	6	3000	21000
	9	3500	18000
	4	3000	23000
C8	9	3000	24000
	0	3500	19000
	2	4000	21000
C9	1	3000	16000
	7	3500	25000
	8	3000	26000
C10	0	3000	26000
	2	3500	25000
	1	3000	26000

Figure 6-3. NDI ecimen Fatigue History (Cont'd)

the next starter flaw was cut and so on. The result was different numbers of cycles applied to each starter flaw and different final crack lengths on the same specimen. For example, in Specimen B-20 in Figure 6-3, the starter flaw was cut at position 3 first. After 3000 cycles, a starter flaw was cut at position 1. The result was two different final crack lengths as shown in Figure 6-4.

After all specimens were cracked, each was again placed in the drill fixture and the remaining hole positions were piloted to 7/64 inch diameter. The specimens were then given an independent visual inspection to verify crack locations and lengths. Specimen serialization was then masked with lead tape and all surfaces were primed with epoxy and given a polyurethane topcoat. All holes were drilled to 11/64 inch diameter, reamed to 0.191 inch, and countersunk for 100 degree 3/16 inch flush head HiLoks. A detailed specimen drawing and condensed fabrication sequence are presented in Figure 6-5.

After final preparation each flaw location was checked to confirm that the flaw could not be detected with the unaided eye. All raw data were then reduced ro yield the crack growth history data in Figure 6-3 and the crack length/location data in Figure 6-4. The data are referenced to a specimen orientation with the countersinks facing upward and the stamped identifications on the right-hand end. Fatigue history is provided in Figure 6-3. Surface roughness of both bare metal and epoxy primed, polyurethane final coated panels does not exceed 64 RMS finish.

Data sheets for technician reporting of inspection results were designed for graphic depiction of fatigue cracks. Figure 6-6 shows a blank data form, the format being consistent with those used on the basic reliability program. Grading of data sheets were accomplished at Lockheed-Georgia using the tally sheet format shown in Figure 6-7.

NDI Procedures

NDI procedures commensurate with the -36 manual format and content were developed for ultrasonic shear wave and eddy current bolt hole operations on the screening sample panels. These procedures are attached as Appendix C. Ultrasonic shear wave scans were accomplished with countersink fasteners in-place and eddy current bolt hole scans accomplished with fasteners removed.

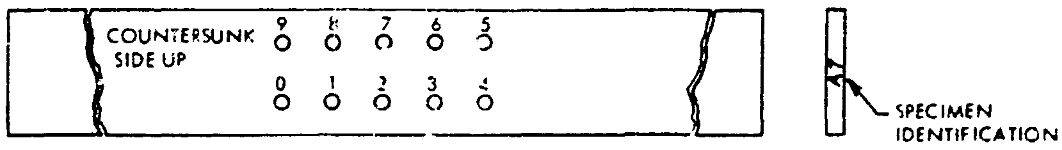
Validation of Procedures and Test Results

Procedures were validated by engineering personnel before assignment to technicians in the field and depot environment. Eddy current bolt hole scans produced significant indications on all cataloged fatigue cracks. No ambiguous indications were evidenced from non-flawed holes, due to the high quality surface condition of the hole walls.

Ultrasonic NDI validation was conducted in detail with relative echo signal amplitude readings taken on each fatigue crack. Instrument operation data are given in Figure 6-8 and results are provided in Figure 6-9. The procedure calls for the instrument gain setting to 80 percent of full screen height on the echo obtained from a second reflection bounce(1) from a 0.05" corner slot echo (see Figure 3, page 7 of Appendix C). This setting provided a low level response from fatigue cracks in the 0.05" to 0.12" length range using a direct shot at

(1) The second reflection was specified to keep the transducer face off the fastener head which can protrude slightly and decouple the ultrasonic energy path.

NDI SPECIMEN DEFINITIONS



THROUGH-THE-THICKNESS CRACK LOCATIONS AND LENGTHS

SPECIMEN NUMBER	CRACK LENGTH, INCHES, AT HOLE NUMBER									
	0	1	2	3	4	5	6	7	8	9
A1					.21 "0"					
A2		.07 "0"								
A3							.14 "I"			
A4										.21 "0"
A5							.14 "0"			
A6		.14 "0"								
A7		.14 "I"								
A8										.30 "0"
A9	.30 "I"									
A10			.20 "0"							
A11										.07 "0"
A12	.14 "I"									
A13								.21 "I"		
A14				.07 "I"						
A15				.30 "I"						
A16									.09 "0"	

"0" INDICATES CRACK IN DIRECTION OF SPECIMEN OUTER EDGE
"I" INDICATES CRACK GROWN IN DIRECTION OF SPECIMEN CENTER

Figure 6-4. Fatigue Crack Sizes and Locations in Flat Panels

SPECIMEN NUMBER	CRACK LENGTH, INCHES, AT HOLE NUMBER									
	0	1	2	3	4	5	6	7	8	9
A17							.30 "I"			
A18								.21 "I"		
A19			.07 "I"							
A20	.21 "0"									
A21				.07 "0"						
A22			.28 "0"							
A23					.30 "0"					
A24	.14 "I"									
A25						.21 "0"				
A26			.30 "0"							
A27									.30 "0"	
B1				.22 "I"			.14 "0"			
B2				.06 "I"	.23 "I"					
B3			.16 "I"							.14 "0"
B4	.08 "0"			.21 "0"						
B5								.23 "0"		.05 "I"
B6			.12 "0"		.22 "0"					
B7	.05 "I"							.24 "0"		
B8		.21 "0"		.14 "I"						
B9				.13 "I"						.16 "I"
B10		.33 "0"					.18 "0"			
B11					.29 "I"				.30 "0"	
B12		.12 "I"					.30 "0"			
B13					.31 "I"			.21 "I"		
B14	.28 "I"		.07 "0"							
B15	.33 "I"							.11 "I"		
B16				.28 "I"						.15 "I"
B17	.32 "I"						.28 "0"			
B18				.28 "0"			.09 "0"			

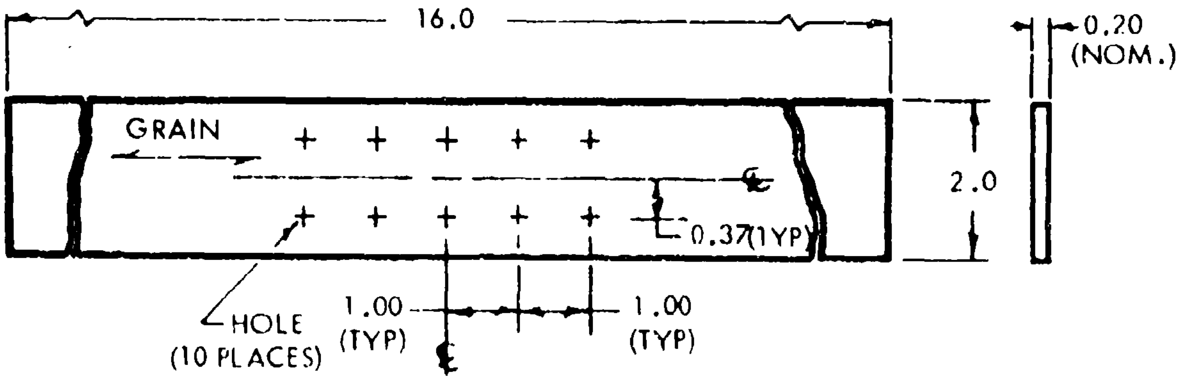
Figure 6-4. Fatigue Crack Sizes and Locations in Flat Panels

SPECIMEN NUMBER	CRACK LENGTH, INCHES, AT HOLE NUMBER									
	0	1	2	3	4	5	6	7	8	9
B19								.08 "0"		.23 "0"
B20		.05 "I"		.14 "0"						
B21		.24 "I"						.28 "0"		
B22		.14 "I"		.29 "0"						
B23					.35 "0"		.07 "I"			
B24			.08 "0"							.19 "I"
B25						.08 "0"	.28 "I"			
B26				.14 "I"		.14 "0"				
B27	.20 "I"		.30 "I"							
B28						.07 "0"				.33 "0"
B29	.08 "I"			.07 "I"						
B30	.16 "I"						.06 "I"			
B31	.21 "0"		.05 "I"							
B32			.31 "I"		.08 "I"					
B33	.34 "0"							.05 "0"		
C1			.19 "I"			.17 "0"		.12 "I"		
C2	.06 "I"			.07 "I"						.19 "0"
C3			.09 "I"			.06 "I"	.20 "0"			
C4			.20 "0"			.17 "I"			.11 "0"	
C5				.12 "0"	.29 "I"		.09 "0"			
C6		.05 "0"		.19 "0"		.20 "0"				
C7					.30 "I"		.17 "I"			.14 "0"
C8	.13 "0"		.19 "0"							.31 "0"
C9		.07 "I"						.16 "I"	.16 "0"	
C10	.32 "I"	.33 "I"	.33 "0"							
D1				.05 "0"						
D2									.05 "I"	
D3									(1)	
D4										
D5										
D6										
D7										

(1) EDM CORNER FLAW BACK SIDE

Figure 6-4. Fatigue Crack Sizes and Locations in Flat Panels

SPECIMEN CONFIGURATION



FABRICATION SEQUENCE

1) Shear Oversize Blanks
2) Profile Blanks to Above Dimensions
3) Identify Specimens Using Metal Stamp
4) Pilot Drill, 7/64-Dia., All Holes Requiring Cracks
5) Cut Starter Flaws (thru flaw approx. 0.02-inch) Using Jewelers Saw
6) Fatigue Cycle Until Crack Initiates and Reaches Desired Length
7) Pilot Remaining Hole Locations, 7/64-Dia.
8) Mask Specimen Identification Using Lead Tape
9) Prime All Surfaces with Epoxy Plus One Coat Polyurethane
10) Drill All Holes 11/64 Dia.
11) Ream all Holes 0.191 Inch
12) Countersink for 100-Degree 3/16-Inch Flush Head HiLok

Figure 6-5. Specimen Configuration and Fabrication Sequence

SAMPLES G1-G70

Base ___
Technician ___
Ultrasonic ___
Eddy Current ___

EXAMPLE:

Crack Marker Sample ID

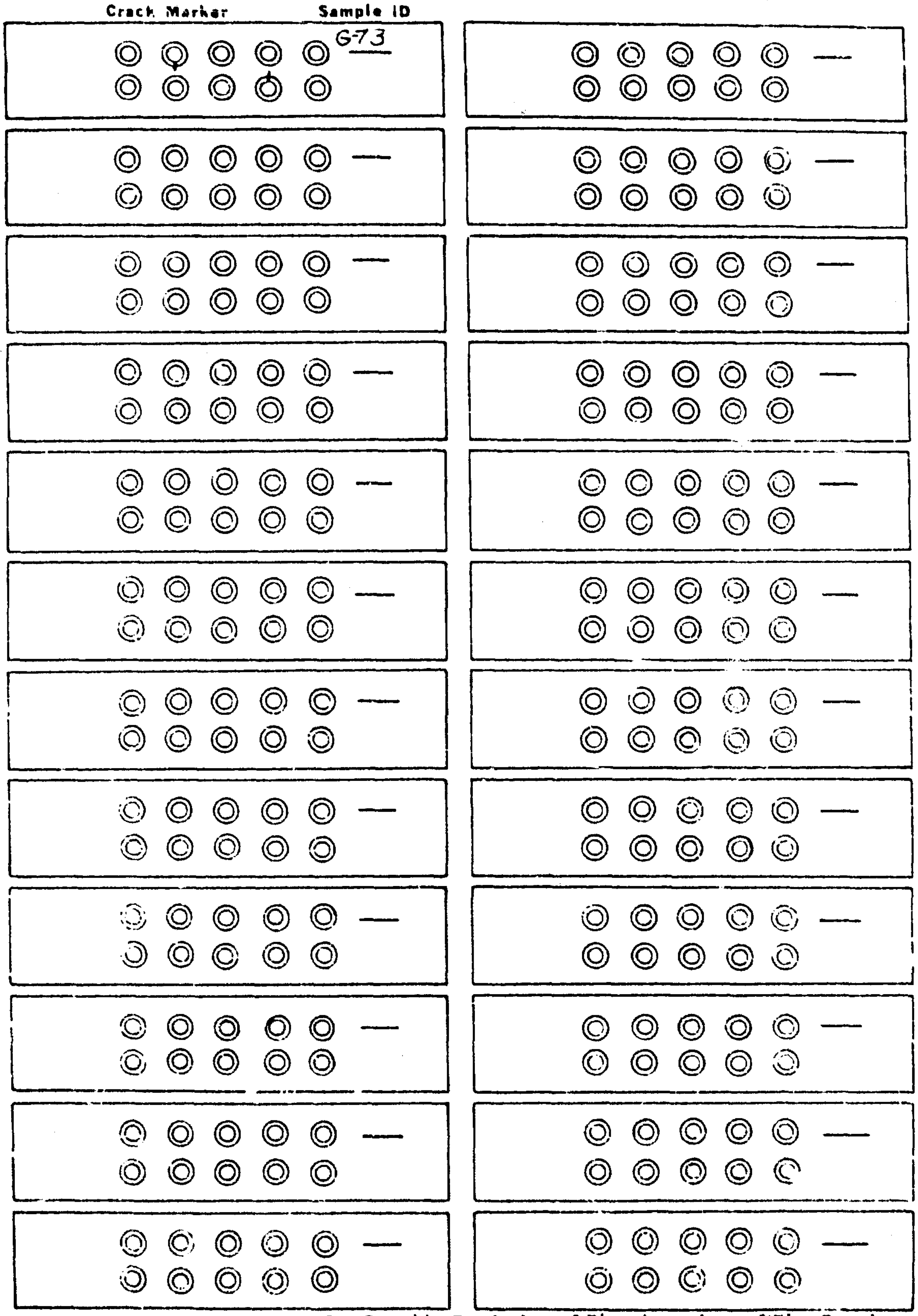


Figure 6-6. Raw Data Form for Graphic Depiction of Flaw Locations of Flat Panels

		CLASS	TOTAL OPPORTUNITIES	FINDS	MISSES
TEST SITE CLASS	____				
INSPECTOR PROFIC. LEVEL	____	I	32		
STRUCTURAL TYPE	____	II	29		
INSPECTION TYPE	____	III	30		
TEST SITE	____ ____	IV	32		
TECHNICIAN	____ ____				

		FLAW CLASS	I	II	III	IV
NDI METHOD	____ ____	FLAW CLASS	I	II	III	IV
FALSE ALARMS	____ ____ ____ ____	FLAW SIZE RANGE	.050 .100	.101 .175	.176 .250	.250 .350

SPECIMEN/HOLE NO.	FLAW SIZE	FIND	MISS	SPECIMEN/HOLE NO.	FLAW SIZE	FIND	MISS
A1/4	III			B1/3	III		
A2/1	II			B1/6	II		
A3/6	II			B2/3	I		
A4/9	III			B2/4	III		
A5/6	I			B3/9	II		
A6/1	II			B3/2	II		
A7/1	II			B4/0	I		
A8/9	IV			B4/3	III		
A9/0	IV			B5/7	III		
A10/2	I			B5/9	I		
A11/9	III			B6/2	II		
A12/0	II			B6/4	III		
A13/7	III			B7/0	I		
A14/3	I			B7/7	III		
A15/3	IV			B8/1	III		
A16/8	I			B8/3	II		
A17/6	IV			B9/3	II		
A18/7	III			B9/9	II		
A19/2	I			B10/6	III		
A20/0	III			B10/1	III		
A21/3	I			B11/4	IV		
A22/2	IV			B11/[illegible]	IV		
A23/4	IV			B12/1	II		
A24/0	II			B12/6	IV		
A25/5	III			B13/4	IV		
A26/2	IV			B13/7	III		
A27/1	IV			B14/2	I		

Figure 6-7. Tally Sheet for Grading NDI Response on Flat Panels

SPECIMEN/HOLE NO.	FLAW SIZE	FIND	MISS	SPECIMEN/HOLE NO.	FLAW SIZE	FIND	MISS
B14/0	IV			C1/7	II		
B15/0	IV			C1/2	II		
B15/7	II			C1/5	III		
B16/3	IV			C2/3	I		
B16/9	II			C2/9	III		
B17/6	IV			C2/0	I		
B17/0	IV			C3/6	III		
B18/6	I			C3/2	I		
B18/2	IV			C3/5	I		
B19/7	I			C4/2	II		
B19/9	III			C4/8	II		
B20/3	II			C4/5	III		
B20/1	I			C5/4	IV		
B21/1	IV			C5/3	II		
B22/3	III			C5/6	I		
B22/1	II			C6/1	I		
B23/6	I			C6/3	I		
B23/4	IV			C6/5	III		
B24/2	I			C7/6	III		
B24/9	III			C7/9	II		
B25/5	I			C7/4	IV		
B25/6	IV			C8/9	IV		
B26/5	II			C8/0	II		
B26/3	II			C8/2	III		
B27/0	III			C9/1	I		
B27/2	IV			C9/7	IV		
B28/5	I			C9/8	II		
B28/9	IV			C10/0	IV		
B29/0	I			C10/2	IV		
B29/3	I			C10/1	IV		
B30/6	I						
B30/0	II						
B31/0	III						
B31/2	I						
B32/2	IV						
B32/4	I						
B33/0	IV						
B33/7	I						

Figure 6-7. Tally Sheet for Grading NDI Response on Flat Panels (Cont'd)

NONDESTRUCTIVE INSPECTION DATA ULTRASONIC		
(1) Air Force Base N/A		
(2) Assigned AF NDI Technician ID No. Sproat	(3) Date 7/19/77	(4) Sample Identification Technician Screening Samples

(5) Equipment/Material Used:

Ultrasonic Inst. Mfg. Automation Model UJ Serial No. 10640-7

Model ______ Serial No. ______

Transducer M). Automation M›del 57A3065 Serial No. 27146

Freq. 5.0 MHz Angle 60°A Size 1/4" Sq. Couplant Light Oil

(6) Inspection Procedure Identification: ______

Calibration Std. ID No. ______

(7) Equipment Calibration Settings:

Sweep 0.5-5 Pulse Length 10° CW Frequency 5.0 MHz

Video Filter Pos. 4 Reject OFF Test Mode Pulse Echo

20db Toggle Sensitivity 14db (-1 Toggle) Damping None

.75 KHz Repetition Rate Other (Record under Comments)

(8) Inspection Start/Stop Times (Date if after Item 3 Date)

Start	Stop	Start	Stop

(9) Inspector Comments (Equipment Adjustments, Inspection Procedure Variations, Other Comments)

Figure 6-8. Ultrasonic Instrument Settings for Flaw Echo Amplitude Readings

Crack Length (In.)	dB Relative	Spec. Number	Hole Position	Crack Length (In.)	dB Relative	Spec. Number	Hole Position	Crack Length (In.)	dB Relative	Spec. Number	Hole Position
.05	+10*	B-7	0	.12	- 6*	C-5	3	.19	- 10	C-6	3
.05	+10*	B-20	1	.12	0	C-1	7	.19	- 6	B-24	9
.05	0*	C-6	1	.13	-10	C-3	0	.19	- 11	C-2	9
.05	+ 2*	B-31	2	.13	- 8	B-9	3	.20	- 14	B-27	0
.05	- 5*	B-5	9	.14	- 4	A-12	0	.20	- 8	A-10	2
.06	+ 2*	C-2	0	.14	- 6	A-24	0	.20	- 10	C-4	2
.06	+10	B-2	3	.14	-14	A-6	1	.20	- 10	C-6	5
.07	+10	A-2	1	.14	-12	A-7	1	.20	- 6	C-3	6
.07	Undetect.	A-19	2	.14	- 2	B-22	1	.21	- 8	B-31	0
.07	+10	B-14	2	.14	- 2	B-8	3	.21	- 6	B-8	1
.07	+ 6*	A-14	3	.14	- 6	B-20	3	.21	- 6	B-4	3
.07	+ 8	A-21	3	.14	- 1	B-26	3	.21	- 4	A-1	4
.07	+13*	B-29	3	.14	0	B-26	5	.21	- 6	A-25	5
.07	0*	C-2	3	.14	- 2	A-3	6	.21	- 16	A-13	7
.07	+14*	B-28	5	.14	+ 2	A-5	6	.21	- 16	A-18	7
.07	+ 8	B-23	6	.14	- 2	B-1	6	.21	- 12	B-13	7
.08	0*	B-4	0	.14	0	B-3	9	.21	- 6	A-4	9
.08	+ 4	B-29	0	.14	- 4	C-7	9	.22	- 4	B-1	3
.08	+ 6	B-24	2	.15	- 6	B-16	9	.22	- 10	B-6	4
.08	+ 4*	B-32	4	.16	- 8	B-30	0	.23	- 3	B-2	4
.08	- 4*	B-25	5	.16	0	B-3	2	.23	- 10	B-5	7
.08	+ 2	B-19	7	.16	- 6	C-9	7	.23	- 6	B-19	9
.09	- 2*	C-3	2	.16	- 2	B-9	9	.24	- 2	B-21	1
.09	+ 8*	B-18	6	.17	- 5	C-1	5	.24	- 3	B-7	7
.09	- 2*	C-5	6	.17	- 8	C-4	5	.28	- 8	B-14	0
.09	- 2	A-16	8	.17	+ 2	C-7	6	.28	- 18	B-22	2
.11	0	B-15	7	.18	+ 6	B-10	6	.28	- 18	B-16	3
.11	- 8	C-4	8	.18	- 6	C-9	8	.28	- 4	B-18	3
.12	0	B-12	1	.19	- 6	C-1	2	.28	- 12	C-17	6
.12	0	B-6	2	.19	- 9	C-8	2	.28	- 14	B-25	6

*Low Level Response Requiring Direct Shots at the Flaw to Obtain an Echo – This configuration is not called for in the NDI Procedure

Figure 6-9. Relative Ultrasonic Echo Amplitudes Obtained from Cataloged Flaws in Flat Panels

TABLE III. RELATIVE ULTRASONIC ECHO AMPLITUDES... (continued)

Crack Length (In.)	db Relative	Spec. Number	Hole Position
.29	- 14	B-22	3
.29	- 8	C-5	4
.30	- 10	A-9	0
.30	- 2	A-26	2
.30	- 14	B-27	2
.30	- 4	A-15	3
.30	- 10	A-23	4
.30	- 10	C-7	4
.30	- 20	A-17	6
.30	- 10	B-12	6
.30	- 10	A-27	8
.30	- 9	B-11	8
.30	- 4	A-8	9
.31	- 10	B-32	2
.31	- 16	B-13	4
.31	- 20	C-8	9
.32	- 18	B-17	0
.32	- 8	C-10	0
.33	- 14	B-15	0
.33	- 12	B-10	1
.33	- 14	C-10	1
.33	- 10	C-10	2
.33	- 8	B-28	9
.34	- 6	B-33	0
.35	- 18	B-23	4

Figure 6-9. Relative Ultrasonic Echo Amplitudes... (Cont'd)

the flaw and an unreliable test with a second reflection bounce. No additional gain was called for in spite of this problem because of the prohibitive baseline noise level observed with added gain. The adjustments to obtain 80 percent of full screen height on the cracks, as presented in Figure 6-9, are listed as positive values where added gain was required to bring the signal up to the 0.05" corner slot reference level. Negative values indicate the converse; reduced gain requirements to obtain 80 percent of full screen height on larger flaws.

A bare (unpainted) reference panel with the 0.05" (0.003" width) EDM corner slot was used as the ultrasonic instrument gain reference. Scheduling constraints precluded its being placed into the painting sequence applied to the rest of the panels. A plot of relative gain versus crack length in Figure 6-10 reveals the combined effect of paint and the difference between an EDM slot and actual fatigue cracks. Cracks in the 0.05" to 0.08" length range require from 2 to 10 db additional gain to obtain a signal height equivalent to the 0.05" EDM slot. The plot also reveals a good deal of scatter, especially for flaw lengths greater than the panel thickness of 0.20". Points are not plotted for those readings accompanied by an asterisk in Figure 6-9, since they are for direct shots at the flaw.

Noise amplitude measurements were made at random locations on the panels near holes without flaws. In all cases, the noise amplitude did not exceed 10 percent of full screen height or 12.5 percent of the 0.05" EDM echo reference level.

Nondestructive Inspection of Flat Panels

These specimens were incorporated into the NDI Reliability Program at Tinker Air Force Base, Midwest City, Oklahoma, in July 1977, and inspection data were obtained there and also at the remaining bases in the program consisting of MacDill Air Force Base, Robins Air Force Base, Charleston Air Force Base, and Shaw Air Force Base. Technicians found these specimens to be an easy and straightforward inspection task. Their only complaint was the fact that there were so many specimens to be inspected.

A total of 25 ultrasonic and eddy current inspections were accomplished during the program. Inspection results and comparisons of results with data obtained from the inspection of other program structure samples can be found in Section XI.

Since flaw lengths were accurately made and measured when these specimens were constructed, they were not destroyed to obtain flaw length measurements as was necessary with the aircraft structural samples.

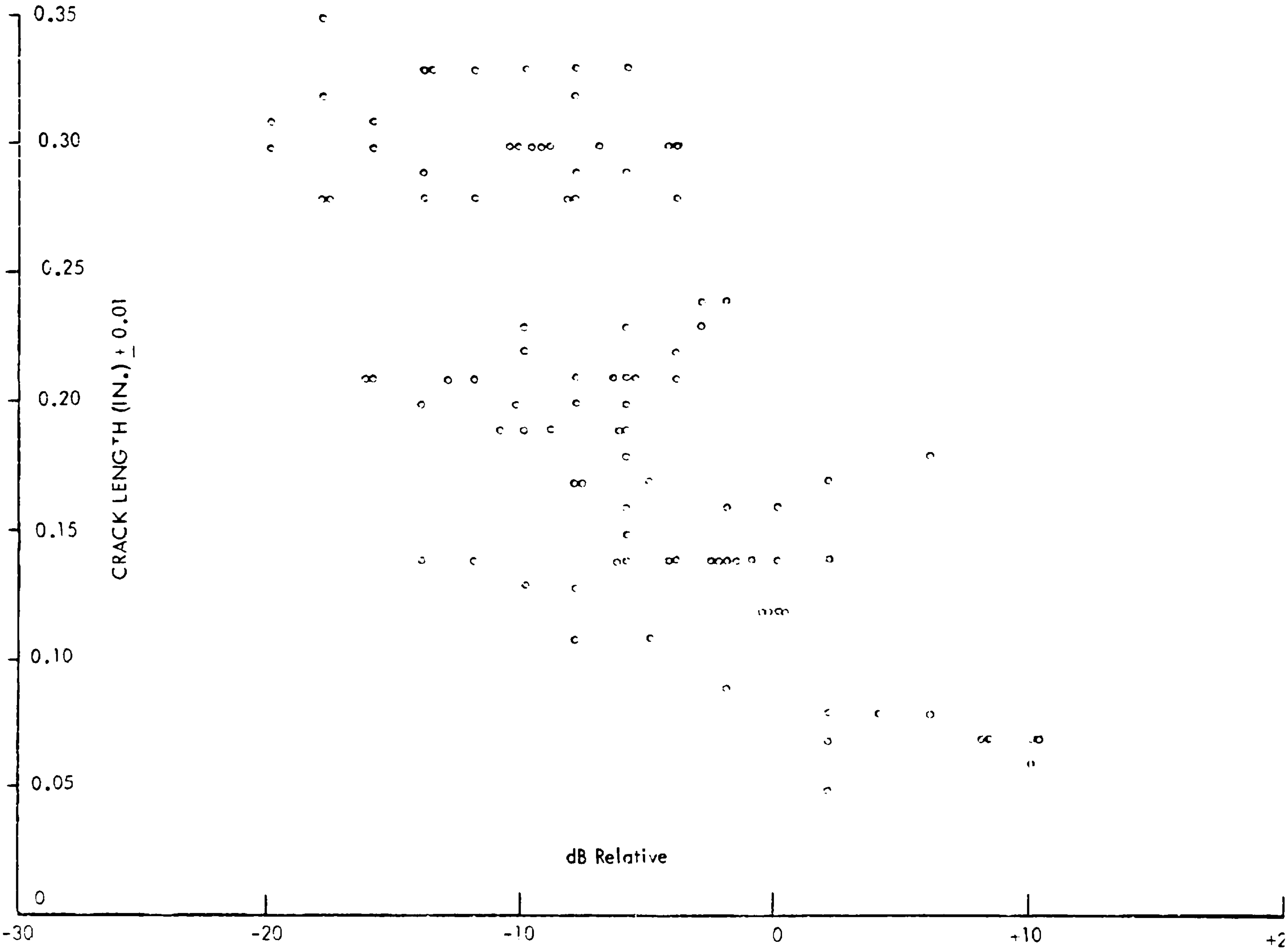


Figure 6-10. Relative Ultrasonic Echo Amplitude as a Function of Fatigue Crack Length

SECTION VII. TEARDOWN EVALUATION

The purpose of the teardown examination of the structure samples used in this program was to accurately determine and fully characterize their flaw content. Flaw indications were initially catalogued and length estimates made in the planning phase of the program by careful visual and eddy current examination. The teardown inspection provided the following additional information:

a) direct measurement of identified flaws

b) confirmation of flaw existence at locations which exhibited high incidences of "false calls"

c) discovery of additional flaws, unknown in the planning phase

d) elimination from the list of flaws, those sites which exhibited NDI indications but contained no actual flaws

The sequence of tasks which composed the complete teardown examination are detailed in the following sections and are schematically presented in Figures 7-1A & 7-1B. Chemical processing of surfaces to enhance detection was applied to all samples. The composition and application data for the chemical agents are provided in Figure 7-2.

Initial Preparation

Structure samples, Type C, were excluded from teardown because they were machine grown fatigue cracks under closely controlled conditions. The size and shape of those flaws are therefore known with sufficient detail for analyses. Structure Samples A, B, E and F were totally disassembled. The Sample A portion was cut from the intact wing box, rivets sheared off at the buck tail and skins removed from stringers in three pieces. Sample B was treated in the same manner but no initial cutting was required due to their size. Sample D required no disassembly and Sample E breakdown was achieved by unbolting the cracked fittings from the dummy cover plates. Sample F sections were cut from the total box beam and separated into spar caps, webs and web stiffeners. Paint was removed from all structure samples with Turco 5212 paint stripper. After stripping, the samples were cleaned in an alkaline solution, water rinsed, dipped in an acid neutralizing bath, water flushed and oven dried. Photos of the samples after the clean and acid dip operations are presented in Figures 7-3A - 7-3E.

Fluorescent penetrant inspections were performed on the samples with Magnaflux ZL-22A penetrant, emulsified with ZR-10A, water washed, air dried and developed with Magnaflux ZP-13A. The penetrant inspections were conducted by Lockheed-Georgia Quality Assurance Laboratory personnel. Flaw indications were red marker identified on the pieces at all suspect locations. Samples A and B were also inspected further with a special automatic eddy current surface scanning device, developed at Sacramento ALC. Results of the penetrant and special eddy current scans, along with high incidence of "false calls" derived from the field data, were added to the list of flaw suspect locations.

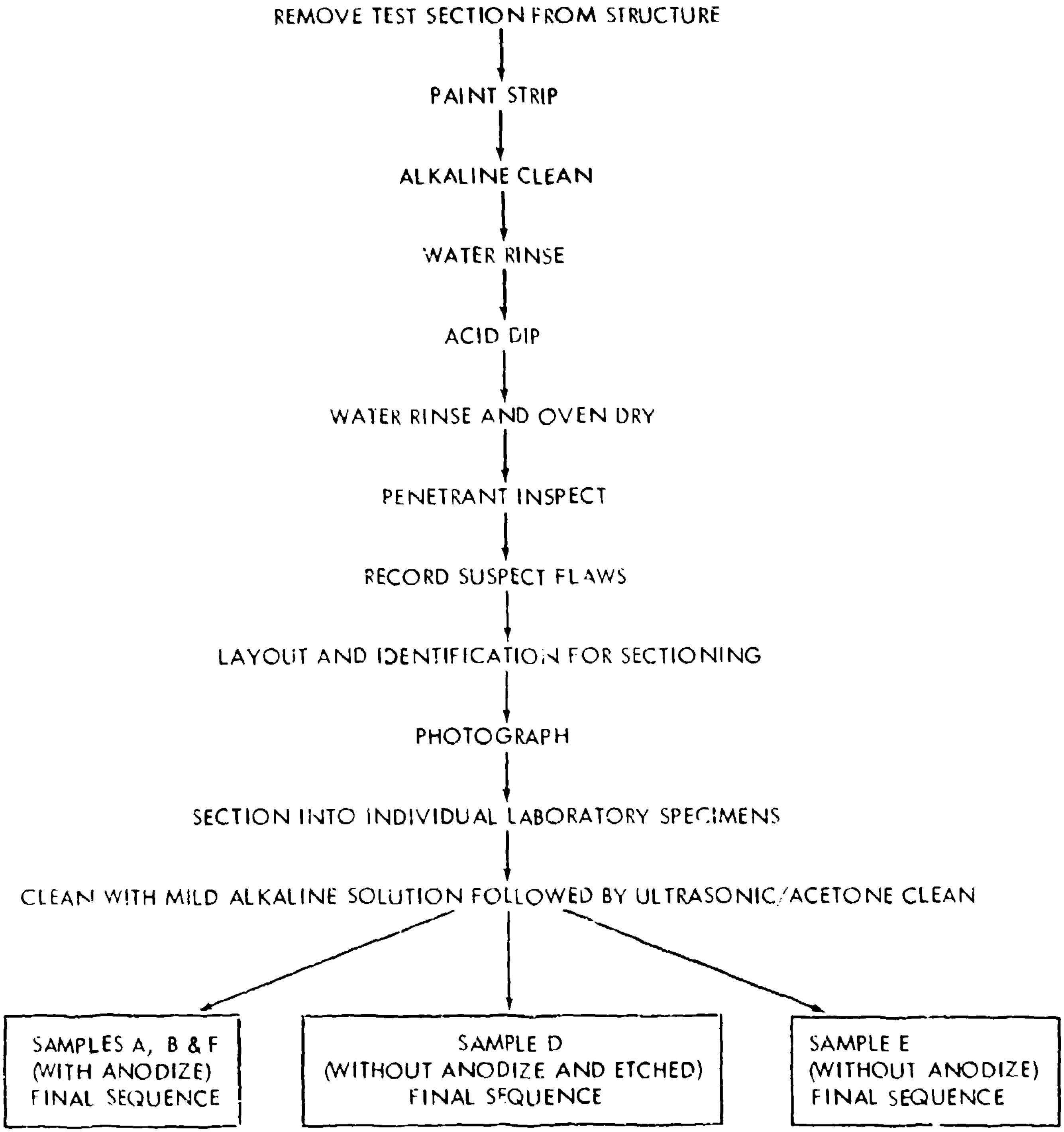


Figure 7-1A. Schematic of Teardown Inspection, Initial Sequence

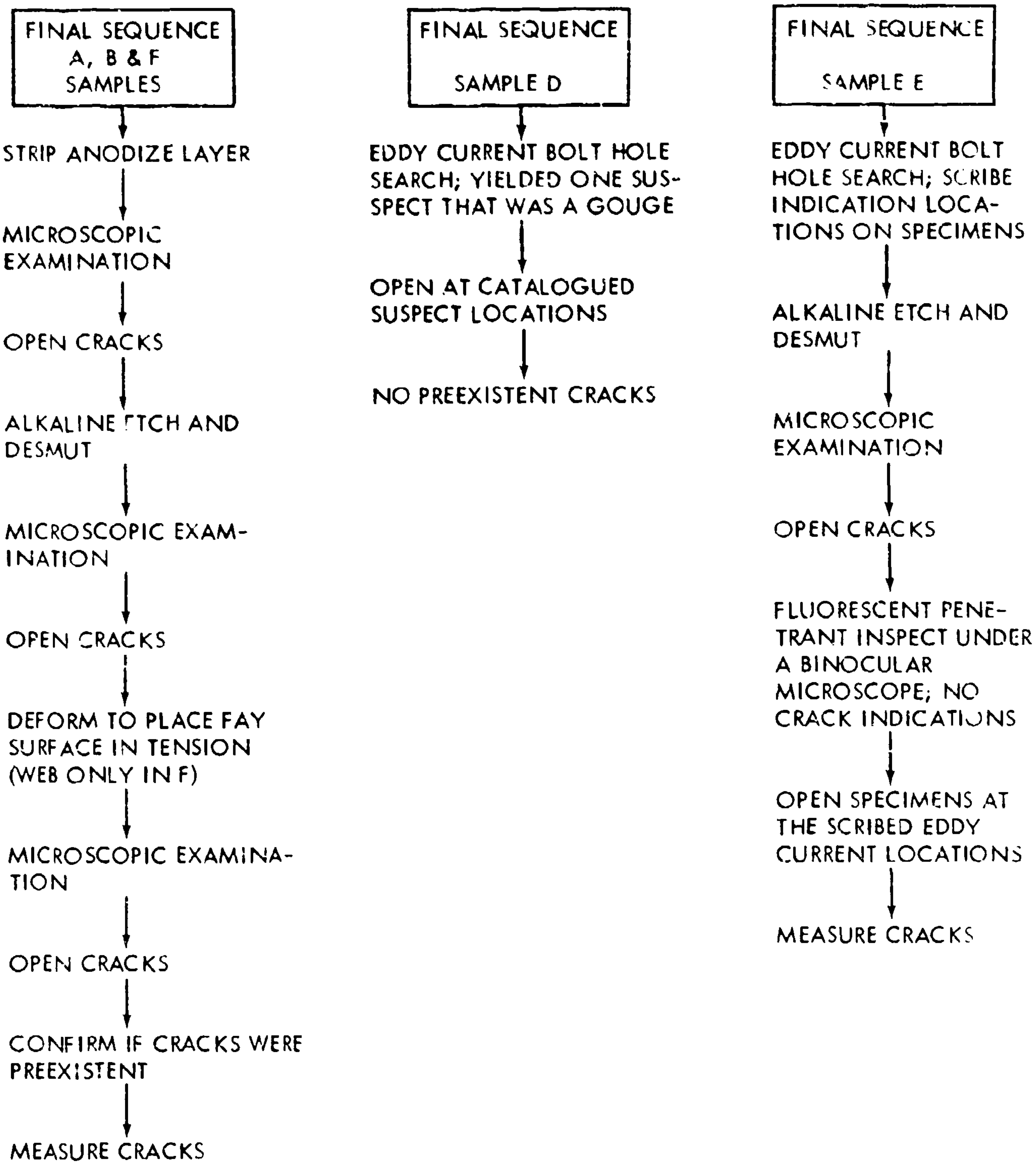
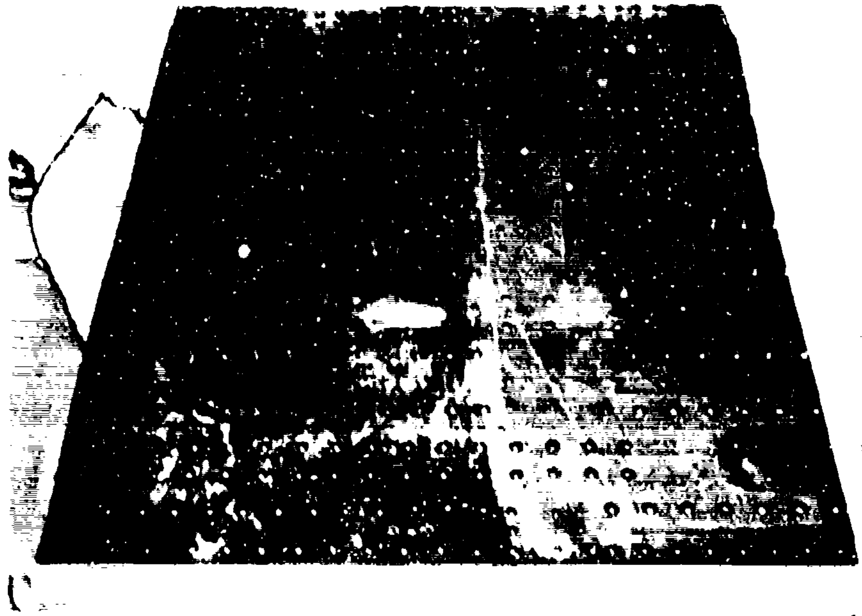


Figure 7-1B. Schematic of Teardown Inspection, Final Sequence

PROCESS	COMPOSITION	APPLICATION TIME	TEMPERATURE
Paint Strip	Turco 5212 Stripper	2 hrs.	Room
Alkaline Clean	5-6% Altrex in H_2O (by volume)	10 min.	160-180°F
Acid Dip	25% H_2SO_4, 5% $Na_2Cr_2O_7$, 70% H_2O (by weight)	10 min.	145-160°F
Anodize Strip	13.5g H_3PO_4, 10g CrO_3 (water to make 500 ml)	6-15 min.	Boiling
Alkaline Etch	3.9% NaOH, 4.0% $NaC_5H_8NO_4$ (Sodium Gluconate) in H_2O (by volume)	8-16 min.	100-120°F
Desmut	(Same as Acid Dip)	10 sec.	Room

Total Metal Removal by all Processes Combined Ranges from 0.0005" to 0.0010"

Figure 7-2. Chemical Treatment Process Details



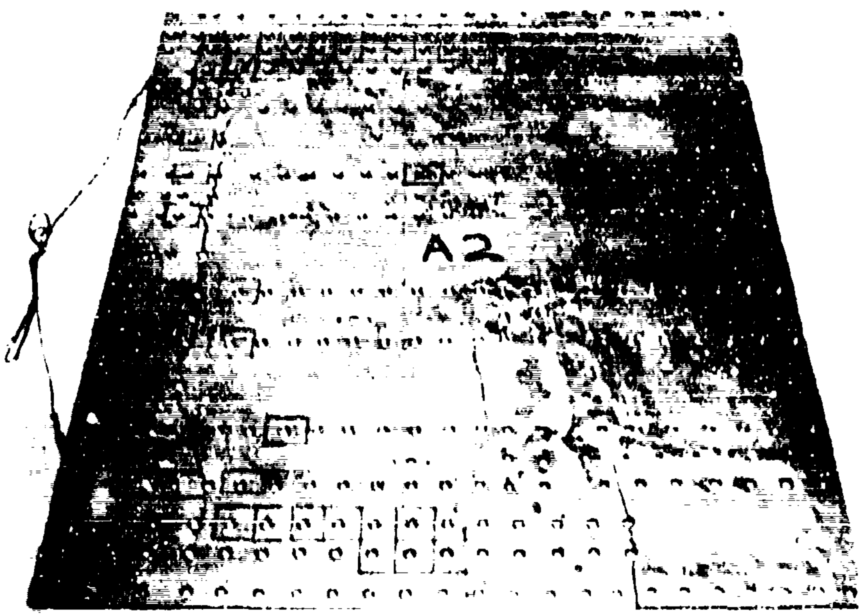
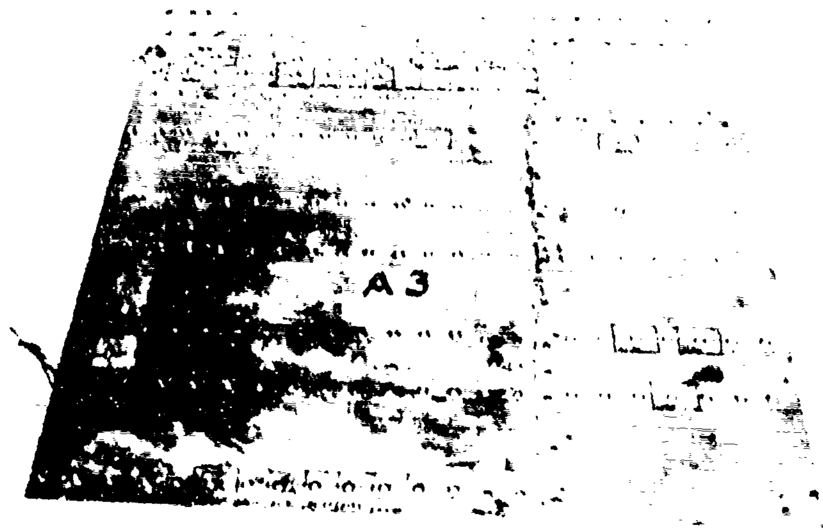


Figure 7-3A. Structure sample Type A - Specimens A1 and A2



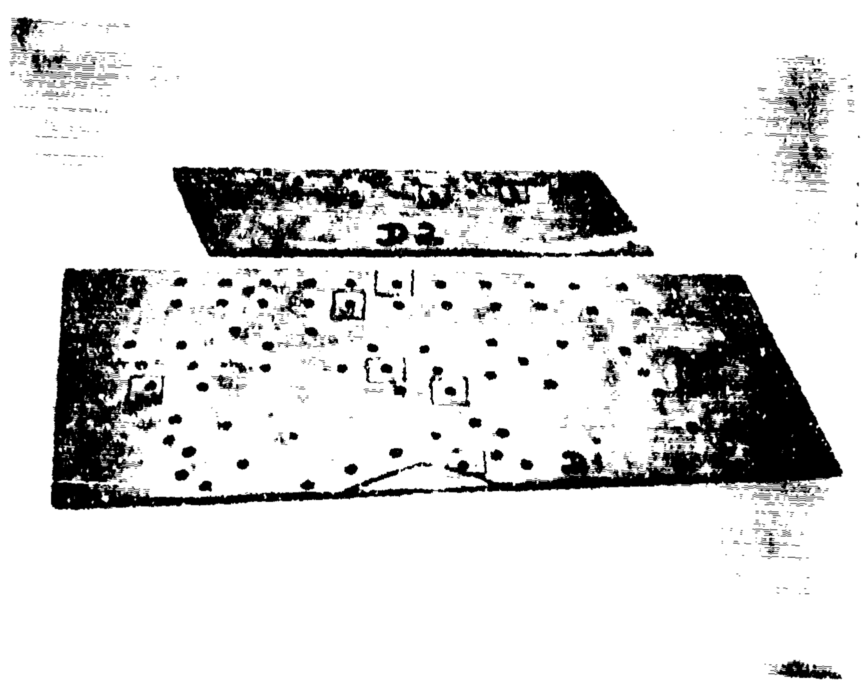
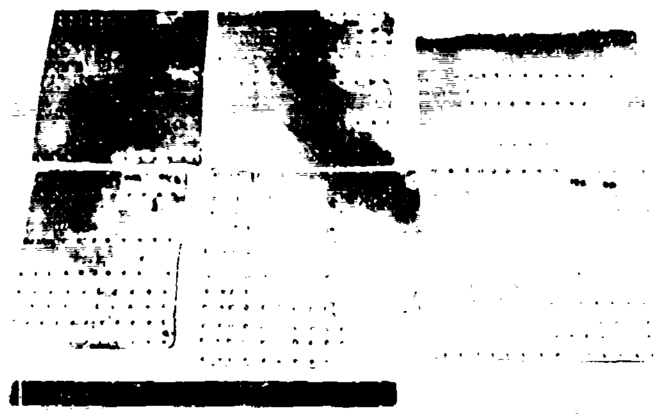


Figure 7.36. Structure Sample Type A and D - Specimens A3, D1 and D2



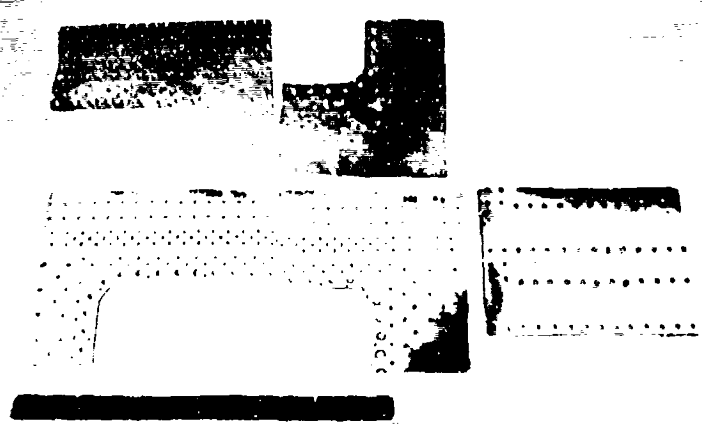


Figure 7-3C. Structure Sample Type B

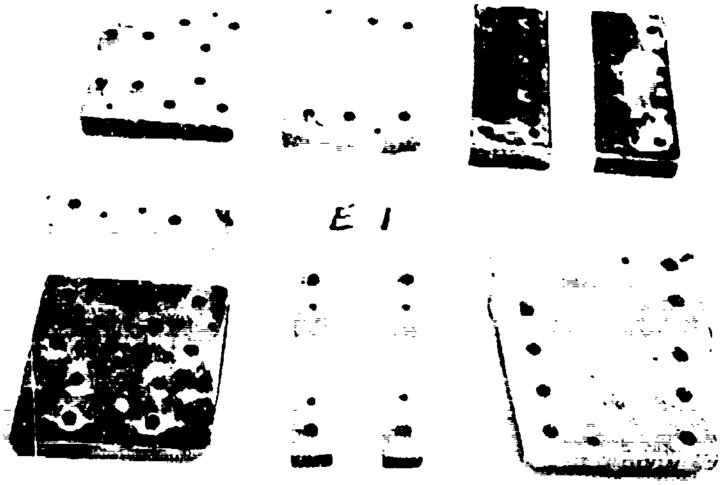
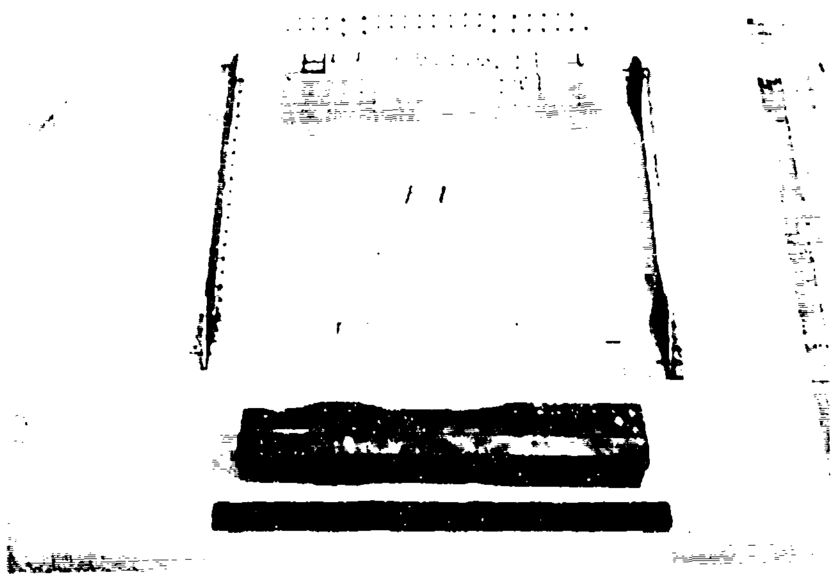


Figure 7-3D. Structure Sample Type E — Specimens E1 and E2



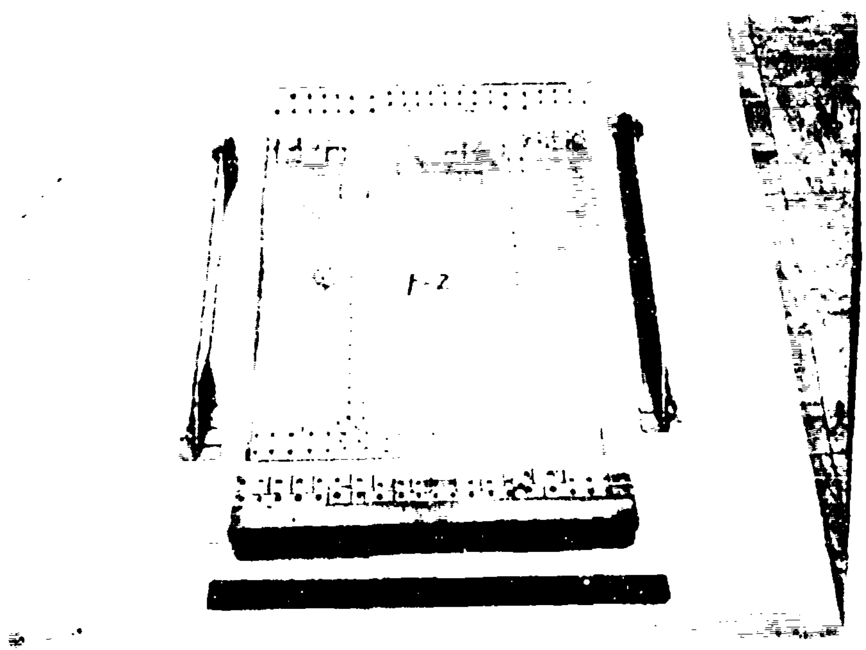


Figure 7-3E. Structure Sample Type F - Specimens F1 and F2

Destructive Inspection

The identification number of each flaw was Vibrotool engraved on the samples next to each fastener hole where there was an identified suspect flaw. Orientation around these fastener holes was maintained by a punch mark at the 12 o'clock position as defined by drawings of the samples. The samples were then marked with lines for saw-cutting into smaller laboratory specimens. The samples were photographed and subsequently saw-cut. Most of the saw-cut specimens were approximately 1 to 2-inch square and contained one suspect flawed fastener hole. The remaining ones were larger with obvious flaws, some of which encompassed more than one fastener hole.

The laboratory specimens were cleaned in a mild alkaline solution, including test tube brush cleaning of hole walls, followed by submersion in an ultrasonic cleaner containing acetone. Initial inspection with a binocular microscope using up to 30X magnification detected some of the flaws which were subsequently opened. The remaining unopened specimens were further processed and inspected for flaws. Those specimens from Samples A, B and F had their anodize layer intact while the anodize layer from Samples D and E had been previously removed prior to incorporation into this program. The specimens from Sample D exhibited considerable pitting which apparently was the result of etching prior to incorporation into the program. Consequently, specimens from A, B and F received different laboratory inspection processing than specimens from D & E. The final inspection step in each specimen group was to inspect for and record hole wall conditions which may be correlated to "false call" indications.

Specimens cut from A, B and F were stripped of their anodize coating and examined microscopically. Those with confirmed flaws were opened. Those which remained unopened were alkaline etched, desmutted and reinspected with a binocular microscope. Those which now exhibited flaws were opened. The remaining unopened specimens were slightly deformed by placing the fay surface in tension in order to partially open any crack. These were reinspected under a binocular microscope. Those which exhibited cracks were opened and those which did not were classified as not being cracked.

Eddy current bolt hole scans to pinpoint crack positions on Sample D specimens yielded only one strong indication of a flaw, but when opened it was a gouge and not a pre-existent (fatigue generated) crack. The remaining specimens were broken open at the catalogued locations of the flaws, but no evidence of pre-existent cracks was observed. The hole walls were noticeably pitted as stated above.

The remaining specimens cut from Sample E were examined using both automatic and manual eddy current bolt hole scans. Detected flaw locations were scribed on each specimen. Four specimens were etched and examined using a binocular microscope and fluorescent penetrant technique. No crack indications were noted. All specimens were then opened at the scribed flaw locations. Generally, the condition of all the hole walls was poor.

Flaw size measurements on the larger fatigue cracks, those greater than 0.10" were made under a binocular microscope with 30X magnification using a steel scale with 0.01" length divisions. Flaws shorter than 0.10" were measured with a graticule on a scanning electron

microscope display. Precision on the optical measurements is ± 0.005" with recorded values rounded-off to the nearest 0.01". Electron microscopy precision is ± 0.0005" with recorded values rounded-off to the nearest 0.001". Flaw plane angularity with respect to the hole axis and the true radial direction were also measured with a protractor overlay. Categories for recording flaw types, dimensions, and angularity are shown graphically in Figure 7-4. The destructive measurements of the catalogued flaws for structure samples "A", "B", "E", and "F" are provided in Figures 7-5 through 7-11. The catalogued flaws for structure samples "C" and "G", whose crack lengths were determined by visual measurement during fatigue cycling, are provided in Figures 7-12 and 7-13. A summary of confirmed flaw size ranges by structure type, along with total number of inspection sites and detection opportunities, is presented in Figure 7-14.

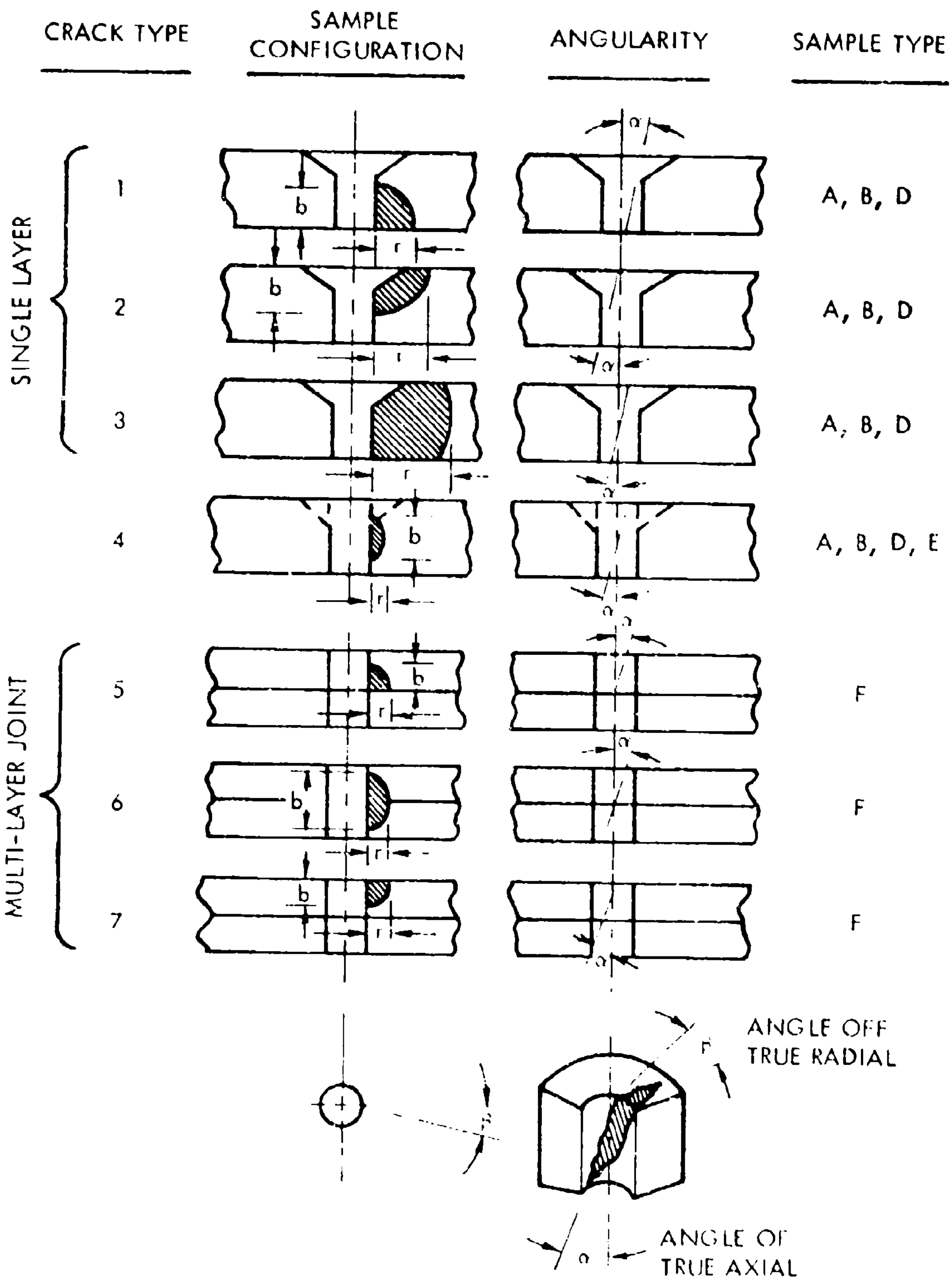


Figure 7-4. Flaw Types and Characteristics for Measurement

Crack ID No.	Crack Type	Crack Length (In.) Axial (b)	Radial (r)	Area x 10^{-4} (In^2)	Angular Deviation (°) Axial (α)	Radial (β)
A277A	3	.09	.14	88		
* A3122	3	.09	.09	43		
A2132	3	.09	.13	79		
A3121	3	.09	.16	106		
A2075	1	.08	.14	63		
A276B	3	.09	.18	124		
A2080	3	.09	.16	106		
A277B	3	.09	.16	106		
A279D	3	.09	.15	97		
* A2125	3	.09	.15	97		
A1133	3	.09	.16	106		
A312A	3	.09	.16	106		
A2078	3	.09	.16	106		
A209B	3	.09	.19	133		
* A2131	3	.09	.17	115		
A1007	3	.09	.18	124		
A108A	3	.09	.17	115		
* A2130	3	.09	.20	142		
A310D	3	.09	.25	187		
A1101	3	.09	.13	79		
A276A	3	.09	.20	142		
A281B	3	.09	.29	223		
A2123	3	.09	.23	169		
A108C	3	.09	.26	196		
A209A	3	.09	.24	178		
A311B	3	.09	.25	187		
A279A	3	.09	.20	142		
A312B	3	.09	.26	196		
A108B	3	.09	.28	214		
A310A	3	.09	.25	187		
A281A	3	.09	.28	214		
A311A	3	.09	.30	232		
A310B	3	.09	.30	232		
A2124	3	.09	.31	241		20
A2020	3	.09	.38	304		20
A104B	3	.09	.45	367		
* A106A	3	.09	.46	376		
A104A	3	.09	.52	430		
* A105A	3	.09	.52	430		
* A106B	3	.09	.60	502		
* A105B	3	.09	.66	556		
* A104C	3	.09	1.05	952		

*Flaw damaged during disassembly - radial length estimated

Figure 7-5. Structure Sample "A" Originally Cataloged Flaw Characteristics

Crack ID No.	Crack Type	Crack Length (In.)		Area $\times 10^{-4}$ (In^2)	Angular Deviation (°)	
		Axial (b)	Radial (r)		Axial (α)	Radial (β)
B033B	3	.09	.15	97		
B0V2A	3	.09	.14	88		
B029B	3	.09	.16	106		
B042A	3	.09	.16	106		11
B025A	1	.06	.05	17.5		
B006B	3	.09	.17	115		
**B001A	3	.09	.12	70		
**B002B	3	.09	.12	70		
B036B	1	.05	.07	21.0		
B040A	1	.07	.07	28.0		
B034B	3	.09	.10	52		
B0U1B	3	.09	.12	70		
B029B	3	.09	.22	160		
B006C	3	.09	.20	142		
**B004A	3	.09	.16	106		
B009B	3	.09	.22	160		
B031B	3	.12	.35	335		
B0U1A	3	.09	.16	106		
B035B	3	.09	.17	115		
**B003A	3	.09	.20	142		
**B005A	3	.09	.20	142		
B027A	3	.12	.28	251		
B008B	3	.09	.30	232		
B026A	3	.09	.20	142		
**B003B	3	.09	.23	169		
B025B	3	.09	.21	151		
*B009A	3	.09	.40	322		27
B028B	3	.09	.23	169		
B026B	3	.09	.23	169		
*B023A	3	.09	.30	232		24
B033A	3	.09	.27	205		
B034A	3	.09	.26	196		
B011B	3	.12	.46	467		
B030A	3	.09	.33	259		
B0V1A	3	.09	.35	277		
B012B	3	.12	.88	971		
B014B	3	.12	.51	527		
B030B	3	.09	.34	268		
B013B	3	.12	.48	491		
B006A	3	.09	.30	232		
B031A	3	.12	.48	491		
B006D	3	.09	.38	304		
B027B	3	.12	.39	383		

Figure 7-6. Structure Sample "B" Originally Cataloged Flaw Characteristics

Crack ID No.	Crack Type	Crack Length (in.)		Area x 10^{-4} (in^2)	Angular Deviation (°)	
		Axial (b)	Radial (r)		Axial (α)	Radial (β)
B028A	3	.09	.41	331		
B013A	3	.12	.79	863		
B008A	3	.09	.67	565		10
B0V1B	3	.09	.49	403		
B011A	3	.12	.84	923		
B014A	3	.12	.86	947		
B012A	3	.12	.88	971		
B007A	3	.09	.74	628		
B007B	3	.09	.73	619		

* Flaw Damaged During Disassembly - Radial Length Estimated

** Flaw in Specimen 301 which was not disassembled - Flaw characteristics Estimated

Figure 7-6. Structure Sample "B" Originally Cataloged Flaw Characteristics (cont'd)

Crack ID No.	Crack Type	Crack Length (In.) Axial (ℓ)	Radial (r)	Area $\times 10^{-4}$ (In^2)	Angular Deviation (°) Axial (α)	Radial (β)
E1047	4	.20	.01	31.4		
E1049	1	.10	.02	15.7	30	5
E2069	1	.20	.03	47.1		
E1019	1	.07	.03	16.5	8	0
E1014	4	.22	.03	103.7	17	0
E1032	1	.20	.07	110.0	8	8
E2003	1	.25	.13	221.9	16	0

Figure 7-7. Structure Sample "E" Originally Cataloged Flaw Characteristics

Crack ID No.	Crack Type	Crack Length (In.)		Area x 10^{-4} (In^2)	Angular Deviation (°)	
		Axial (b)	Radial (r)		Axial (α)	Radial (β)
F666W	5	.01	.007	.55		
F526C	7	.01	.01	.79		
F568C	5	.02	.03	4.7	14	
F581C	5	.05	.06	23.6		
F582C	4	.09	.02	28.2	12	42
F670W	5	.02	.02	3.1		
F672C	4	.11	.04	69.1	10	
F115C	5	.03	.03	7.1		
F171C	5	.06	.07	3.3		
F173C	7	.01	.01	.79		
F615C	7	.01	.06	4.7		
F665C	5	.02	.04	6.3	12	
F111C	5	.03	.09	21.2	10	30
F112W	5	.02	.06	9.4	25	16
F226C	7	.01	.01	.79	13	29
F282C	5	.01	.03	2.4	10	18
F676C	7	.02	.07	11.0	17	
F109W	5	.05	.05	19.6		
F124C	5	.03	.04	9.4	4	40
F166W	3	.10	.47	470.0	11	
F122W	5	.06	.08	37.7		28
F671C	7	.03	.01	2.4		42
F179W	3	.10	.79	790.0		31
F220C	7	.04	.07	22.0		
F218C	7	.05	.08	31.4	12	
F510C	7	.02	.10	15.7		
F121W	3	.10	1.43	1430.0		41
F272C	7	.02	.05	7.9	10	4
F123W	3	.10	.47	470.0		25
F224W	5	.05	.09	35.3		
F169W	3	.10	.79	790.0		
F101W	3	.10	.79	790.0		
F673C	4	.15	.05	117.8	5	
F684C	3	.25	.30	750.0		

Figure 7-8. Stiucture Sample "F" Originally Cataloged Flaw Characteristics

Crack ID No.	Crack Type	Crack Length (In.) Axial (b)	Radial (r)	Area x 10^{-4} (In^2)	Angular Deviation (°) Axial (α)	Radial (β)
R001A	1	.080	.090	40.5		
R002A	3	.09	.17	115		
R003A	1	.07	.08	32.0		
R003B	1	.08	.11	49.5		
R004A	1	.011	.007	0.74		
R006A	1	.07	.07	30.5		
R006B	1	.02	.01	1.5		
R007A	1	.06	.07	24.5		
R008A	1	.01	.005	0.5		
R011A	3	.09	.14	88		
R012A	1	.07	.13	52.0		
R013A	3	.09	.15	97		
R014A	3	.09	.15	97		
R015B	1	.07	.02	8.0		
R016A	3	.09	.11	61		
R017A	1	.08	.13	58.5		
R017B	1	.08	.12	54.0		
R018A	1	.08	.11	49.5		
R018B	1	.04	.02	5.0		
R019A	1	.07	.09	36.0		
R019B	1	.04	.03	7.5		
R020A	1	.027	.027	5.0		
R020B	1	.04	.05	12.5		
R021A	1	.07	.09	36.0		
R021B	1	.06	.06	21		
R022A	1	.07	.10	40.0		
R023A	1	.04	.05	12.5		
R024B	1	.08	.10	45.0		
R025B	4	.007	.003	0.3		
R027A	1	.06	.08	28.0		
R028A	1	.08	.13	58.5		
R029A	1	.08	.10	45.0		
R030A	1	.020	.022	3.3		
R030B	1	.06	.09	31.5		
R031B	1	.02	.02	3.0		
R032A	1	.06	.09	31.5		
R033A	1	.04	.05	12.5		
R034B	1	.07	.08	32.0		
R035B	1	.02	.03	4.5		
R037A	1	.05	.06	18.0		
R037B	1	.08	.12	54.0		
R038B	1	.03	.03	6.0		
R040A	1	.025	.029	5.1		
R041A	1	.07	.09	36.0	5	10

Figure 7-9. Structure Sample "A" Confirmed Suspect Flaw Characteristics Not Originally Cataloged but Verified by Teardown

Crack ID No.	Crack Type	Crack Length (In.)		Area x 10^{-4} (In^2)	Angular Deviation (°)	
		Axial (b)	Radial (r)		Axial (α)	Radial (β)
R042B	1	.02	.02	3.0		
R044A	1	.07	.12	48.0		
R045A	1	.05	.07	21.0		
R045B	1	.04	.05	12.5		
R046A	1	.03	.04	8.0		
R046B	1	.01	01	0.95		
R047A	1	.07	.10	11.5		
R050A	1	.04	.06	15.0		
R051A	1	.06	.09	31.5	14	30
R053A	1	.06	.07	24.5		
R055A	1	.06	.07	24.5		
R056B	3	.09	.15	97		35
R057A	1	.02	.02	3.0		
R058A	1	.01	.02	2.0		
R058B	1	.05	.05	15.0		
R059A	1	.03	.04	8.0		
R062A	1	.03	.04	8.0		
R062B	1	.02	.02	3.0		
R063B	1	.03	.03	6.0		
R065A	1	.008	.010	1.1		
R065B	1	.03	.03	6.0		
R066A	1	.03	.03	6.0		
R066B	1	.03	.05	10.0		
R067A	1	.06	.08	28.0		
R067B	1	.04	.05	12.5		
R068B	1	.04	.06	15.0		
R069A	1	.07	.09	36.0		
R070B	1	.01	.01	1.0		
R071B	1	.05	.07	21.0		
R073A	1	.05	.04	12.0		
R074A	1	.01	.01	1.0		
R075A	1	.02	.02	3.0		
R076A	1	.04	.06	15.0		
R076B	1	.05	.07	21.0		
R077B	1	.04	.06	15.0		
R078A	1	.08	.08	40.4		
R078B	1	.05	.08	24.0		
R079B	1	.04	.05	12.5		
R080A	1	.002	.004	0.56		
R082B	1	.05	.06	18.0		35
R083A	1	.04	.06	15.0		17
R084A	1	.04	.05	12.5		

Figure 7-9. Structure Sample "A" Confirmed Suspect Flaw Characteristics Not Originally Cataloged but Verified by Teardown (Cont'd)

Crack ID. No.	Crack Type	Crack Length (In.)		Area $\times 10^{-4}$ (In^2)	Angular Deviation (°)	
		Axial (b)	Radial (r)		Axial (α)	Radial (β)
R087B	1	.06	.07	24.5		13
R088A	1	.03	.02	4.0		
R089B	1	.05	.04	12.0		
R090B	1	.04	.04	10.0		13
R091B	1	.04	.05	12.5		20
R092B	1	.008	.006	0.66		
R093A	1	.02	.03	4.5		
R095B	1	.07	.08	32.0		
R097B	1	.011	.006	0.63		
R099A	1	.02	.02	3.0		
R099B	1	.06	.06	21.0		
R100A	1	.05	.05	15.0		
R101B	1	.004	.004	0.52		
0B	1	.01	.01	0.95		
02A	1	.035	.025	5.6		
R050B	1	.010	.015	1.5		

Figure 7-9. Structure Sample "A" Confirmed Suspect Flaw Characteristics Not Originally Cataloged but Verified by Teardown (Cont'd)

Crack ID No.	Crack Type	Crack Length (In.)		Area $\times 10^{-4}$ (In^2)	Angular Deviation (°)	
		Axial (b)	Radial (r)		Axial (α)	Radial (β)
S001A	1	.07	.09	36.0		
S002B	4	.02	.01	3.1		
S003A	3	.09	.18	124.0		
S004A	3	.09	.13	79.0		13
S005A	4	.02	.01	3.1		
S005B	1	.004	.006	0.78		
S006A	3	.09	.13	79.0		10
S007A	3	.09	.13	79.0		14
S008B	3	.09	.14	88.0		
S009B	1	.01	.02	1.4		
S010A	1	.02	.02	2.2		
S011A	1	.03	.05	8.6		
S011B	1	.06	.11	34.5	5	
S012B	3	.09	.15	97		12
S013A	4	.02	.01	3.1	9	7
S019A	1	.005	.006	0.75		
S020B	4	.006	.004	0.38		
S021A	1	.004	.004	0.52		
S023A	1	.01	.01	1.0		
S026A	1	.04	.04	10.0		15
S027A	3	.09	.11	61.0		
S028A	1	.10	.10	55.0		
S029A	1	.04	.04	10.0		
S030B	1	.06	.07	24.5		
S031A	1	.08	.10	45.0		
S032A	1	.05	.07	21.0		
S033A	1	.10	.11	60.5		
S034A	1	.04	.07	14.6		
S034B	1	.02	.05	5.5		27
S035A	1	.09	.11	55.0		
S036B	1	.04	.05	12.5		
S009A	1	.03	.04	7.0		16
S010B	1	.02	.03	3.1		
S023B	4	.02	.01	3.1		

Figure 7-10. Structure Sample "B" Confirmed Suspect Flaw Characteristics Not Originally Cataloged but Verified by Teardown

Crack ID No.	Crack Type	Crack Length (In.)		Area $\times 10^{-4}$ (In^2)	Angular Deviation (°)	
		Axial (b)	Radial (r)		Axial (α)	Radial (β)
Sample "E"						
T0001	4	.15	.002	4.7		
T0002	4	.02	.003	0.94		
Sample "F"						
U208W	3	.10	2.17	2170.0		
U101C	3	.25	0.57	1425.0		31
U110W	3	.10	1.43	1430.0		17
U506C	5	.05	0.12	47.1	8	
U603W	3	.10	0.04	40.0	8	
U605W	3	.10	0.14	140.0		
U607C	4	.06	0.02	18.8	15	
U611W	3	.10	1.42	142.0		

Figure 7-11. Structure Samples "E" and "F" Confirmed Suspect Flaw Characteristics Not Originally Cataloged but Verified by Teardown

Crack ID No.	Crack Type	Crack Length (In.)		Area $\times 10^{-4}$ (In^2)	Angular Deviation (°)	
		Axial (b)	Radial (r)		Axial (α)	Radial (β)
C044A	3	0.15	.02	60		
C044B	3	0.15	.06	60		
C039A	7	0.15	.06	28		
C040A	3	0.15	.06	98		
C015A	3	0.15	.06	90		
C015B	3	0.15	.06	90		
C040B	3	0.15	.07	98		
C043B	3	0.15	.08	128		
C043A	3	0.15	.09	128		
C037A	3	0.15	.09	143		
C037B	3	0.15	.10	143		
C014B	3	0.15	.10	158		
C014A	3	0.15	.11	158		
C051B	3	0.15	.12	210		
C034A	3	0.15	.14	210		
C034B	3	0.15	.14	210		
C054B	3	0.15	.14	233		
C051A	3	0.15	.16	210		
C054A	3	0.15	.17	233		
C041A	3	0.15	.17	255		
C041B	3	0.15	.17	255		
C058A	3	0.15	.18	270		
C058B	3	0.15	.18	270		
C047A	3	0.15	.19	285		
C047B	3	0.15	.19	285		
C059A	3	0.15	.20	308		
C059B	3	0.15	.21	308		
C055A	3	0.15	.21	315		
C055B	3	0.15	.21	315		
C050A	3	0.15	.21	323		
C052A	3	0.15	.22	330		
C052B	3	0.15	.22	330		
C029B	3	0.15	.22	345		
C050B	3	0.15	.22	323		
C029A	3	0.15	.24	345		
C057A	3	0.15	.25	375		
C057B	3	0.15	.25	375		
C060B	3	0.15	.27	413		
C060A	3	0.15	.28	413		
C002B	3	0.15	.40	675		
C002A	3	0.15	.50	675		

Figure 7-12. Structure Sample "C" Flaw Characteristics

Crack ID No.	Crack Type	Crack Length (In.)		Area x 10^{-4} (In^2)	Angular Deviation (°)	
		Axial (b)	Radial (r)		Axial (α)	Radial (β)
GA014	3	.20	.21	408		
GA021	3	.20	.07	128		
GA036	3	.20	.14	268		
GA049	3	.20	.21	408		
GA056	3	.20	.14	268		
GA061	3	.20	.14	268		
GA071	3	.20	.14	268		
GA089	3	.20	.30	588		
GA090	3	.20	.30	588		
GA102	3	.20	.20	388		
GA119	3	.20	.07	128		
GA120	3	.20	.14	268		
GA137	3	.20	.21	408		
GA143	3	.20	.07	128		
GA153	3	.20	.30	588		
GA168	3	.20	.09	168		
GA176	3	.20	.30	588		
GA187	3	.20	.21	408		
GA192	3	.20	.07	128		
GA200	3	.20	.21	408		
GA213	3	.20	.07	128		
GA222	3	.20	.28	548		
GA234	3	.20	.30	588		
GA240	3	.20	.14	268		
GA255	3	.20	.21	408		
GA262	3	.20	.30	588		
GA278	3	.20	.30	588		
GB013	3	.20	.22	428		
GB016	3	.20	.14	268		
GB023	3	.20	.06	108		
GB024	3	.20	.23	448		
GB032	3	.20	.16	308		
GB039	3	.20	.14	268		
GB040	3	.20	.08	148		
GB043	3	.20	.21	408		
GB057	3	.20	.23	448		
GB059	3	.20	.05	88		
GB062	3	.20	.12	228		
GB064	3	.20	.22	428		
GB070	3	.20	.05	88		
GB077	3	.20	.24	468		
GB081	3	.20	.21	408		

Figure 7-13. Structure Sample "G" Flaw Characteristics

Crack ID No.	Crack Type	Crack Length (In)		Area $\times 10^{-4}$ (In^2)	Angular Deviation (°)	
		Axial (b)	Radial (r)		Axial (α)	Radial (β)
GB083	3	.20	.14	268		
GB093	3	.20	.13	248		
GB099	3	.20	.16	308		
GB101	3	.20	.33	648		
GB106	3	.20	.18	348		
GB114	3	.20	.29	568		
GB118	3	.20	.30	588		
GB121	3	.20	.12	228		
GB126	3	.20	.30	588		
GB134	3	.20	.31	608		
GB137	3	.20	.21	408		
GB140	3	.20	.28	548		
GB142	3	.20	.07	128		
GB150	3	.20	.33	648		
GB157	3	.20	.11	208		
GB163	3	.20	.28	548		
GB169	3	.20	.15	288		
GB170	3	.20	.32	628		
GB176	3	.20	.28	548		
GB183	3	.20	.28	548		
GB186	3	.20	.09	168		
GB197	3	.20	.08	148		
GB199	3	.20	.23	448		
GB201	3	.20	.05	88		
GB203	3	.20	.14	268		
GB211	3	.20	.24	468		
GB217	3	.20	.28	548		
GB221	3	.20	.14	268		
GB223	3	.20	.29	568		
GB234	3	.20	.35	688		
GB236	3	.20	.07	128		
GB242	3	.20	.08	148		
GB249	3	.20	.19	368		
GB255	3	.20	.08	148		
GB256	3	.20	.28	548		
GB263	3	.20	.14	268		
GB265	3	.20	.14	268		
GB270	3	.20	.20	388		
GB272	3	.20	.30	588		
GB285	3	.20	.07	128		
GB289	3	.20	.33	648		
GB290	3	.20	.08	148		
GB293	3	.20	.07	128		

Figure 7-13. Structure Sample "G" Flaw Characteristics (Cont'd)

Crack ID No.	Crack Type	Crack Length (In.)		Area x 10^{-4} (In^2)	Angular Deviation (°)	
		Axial (b)	Radial (r)		Axial (α)	Radial (β)
GB300	3	.20	.16	308		
GB306	3	.20	.06	108		
GB310	3	.20	.21	408		
GB312	3	.20	.05	88		
GB322	3	.20	.31	608		
GB324	3	.20	.08	148		
GB330	3	.20	.34	668		
GB337	3	.20	.05	88		
GC012	3	.20	.19	368		
GC015	3	.20	.17	328		
GC017	3	.20	.12	228		
GC020	3	.20	.06	108		
GC023	3	.20	.07	128		
GC029	3	.20	.19	368		
GC032	3	.20	.09	168		
GC035	3	.20	.06	108		
GC036	3	.20	.20	388		
GC042	3	.20	.20	388		
GC045	3	.20	.17	328		
GC048	3	.20	.11	208		
GC053	3	.20	.12	228		
GC054	3	.20	.29	568		
GC056	3	.20	.09	168		
GC061	3	.20	.05	88		
GC063	3	.20	.19	368		
GC065	3	.20	.20	388		
GC074	3	.20	.30	588		
GC076	3	.20	.17	328		
GC079	3	.20	.14	268		
GC080	3	.20	.13	248		
GC082	3	.20	.19	368		
GC089	3	.20	.31	608		
GC091	3	.20	.07	128		
GC097	3	.20	.16	308		
GC098	3	.20	.18	348		
GC100	3	.20	.32	628		
GC101	3	.20	.33	648		
GC102	3	.20	.33	648		

Figure 7-13. Structure Sample "G" Flaw Characteristics (Cont'd)

STRUCTURE SAMPLE DETAIL

STRUCTURE SAMPLE IDENTIFICATION	Number of Inspection Sites	Number of Flaw Detection Opportunities	Confirmed Flaw Size Range (Inches)
Type A, C-130 Center Wing Box Section	531	42	0.09 - 1.05 Radial
Type B, C-130 Center Wing Box Segments	500	51	0.05 - 0.88 Radial
Type C, Riser Segments	364	56	0.02 - 0.50 Radial
Type D, KC-135 Lower Wing Plank Segment	105	0	N/A
Type E, F-104 Forged Wing Fittings	52	7	0.07 - 0.25 Axial
Type F, C-5 Wing Spar Configuration	240	45	0.01 - 0.25 Axial 0.01 - 1.43 Radial
TOTAL	1792	201	

Figure 7-14. Summary of Confirmed Flaw Size Ranges by Structure Type; Along with Total Number of Inspection Sites and Detection Opportunities

SECTION VIII. DATA STORAGE AND RETRIEVAL

The large quantity and diverse nature (numerical and narrative mix) of information acquired on the NDI Reliability effort has created a need for an efficient data management system. Additionally, the data management system and processing functions are desired to be compatible with Wright-Patterson Air Force Base computer facilities. A general purpose System 2000 Data Management System, developed by MRI Systems, Inc., Austin, Texas, has been identified as fulfilling the above requirements. Functions of the System 2000 include storage and organization of the data, updating with new inputs, identification and isolation of important data, preparation of reports in any format, computation of averages, sums and other fundamental statistics and production of decision making information. An English-like syntax is used in data handling which eliminates the need for special programming skills to operate.

Subroutines, which are transparent to the data management/operator interface, can be used to calculate variance ratios which are used in testing for significance. Subroutines for confidence level calculations and graphic plots are also transparent to the operator. Programming, data input and initial processing has been accomplished through a Control Data Corporation terminal at Lockheed-Georgia. A transition to full operational capabilities with a complete data repository at Wright-Patterson Air Force Base has been provided as an end product of the parametric analysis effort.

DATA CATEGORIES

The formating of the raw NDI Reliability data has a two-fold objective: (a) arranging a large mass of both numerical and narrative information for convenient storage and retrieval, and (b) data processing to conduct analyses and tests for significance of variables. The first objective is driven by the need to efficiently obtain hard copy printouts of specific raw data by selecting identifier words and to shunt selected data into computational routines. The second objective is to provide graphic information on one variable plotted against a second and to provide statistical calculations necessary for testing for significance.

The information acquired on the NDI Reliability effort has been divided into seven categories: (a) Flaw Size Tabulation, (b) Inspection Results, (c) Individual Inspection Log, (d) Technician Profile, (e) Base Daily, (f) Facility Evaluation, and (g) Equipment Performance. Each category has its contents listed in tabular punched card format to be used as initial computer data input. The following Figures and their associated notes show the detailed format used for inclusion of all the acquired raw data for transcription to punched cards and computer programming operations. They contain both encoding information and narrative descriptions for the complete transcribing process.

DATA BASE DEFINITION

The data management has been accomplished by assigning names or descriptions to a data base composed of elements in a hierarchy of existing interrelationships. A schematic of the data base used in this program is presented in Figure 8-10. The highest level descriptor is the "Sample Type" because it was established as the most fundamental element in the data

acquisition process; all other descriptions are subordinate. Unique sets of flaw identifications and characteristics are attached to each Sample Type which has a large number of subordinate results accompanying every flaw. The next lower level of subordination is branched into two categories: Technician Profiles and the Facility Evaluations. Both of these descriptors have four subordinate elements as shown in the schematic. Each of the descriptors is assigned a hierarchical index value with the smaller numbers at the top and larger numbers signifying a position of lower accession priority. A partial list of the data base definition is provided in Figure 8-11 in the COBOL language for System 2000 input.

DATA RETRIEVAL

Raw data are directly assessed by a SYSTEM 2000 command labeled "LIST". This command produces outputs in columnar format with user-specified column headings. The data are screened with standard "WHERE" clause qualifying descriptors such as List Results Where Sample Type is "A" and NDI Method is "UT". Graphic plots of flaw detection probabilities are developed by "WHERE" clause descriptors along with a four card input command entitled "NDI PLOT". A number of these graphic plots are presented in Section XI, "Detailed Reliability Findings".

COLUMN	DATA	FORMAT	REMARKS
1	Data Type (1)	X	
2, 3	Base ID	XX	
4	Start Date: Year	X	5, 6, 7, or 8 Note 1
5, 6	Month	XX	Ø1 - 12
7, 8	Day	XX	Ø1 - 31
9	Completion Date: Year	X	5, 6, 7, or 8
10, 11	Month	XX	Ø1 - 12
12, 13	Day	XX	Ø1 - 31
***	Following Data obtained from Items 1-5 of Facility		
***	Evaluation Sheet, See Note 2		
14	Shop Type	A	G-General, H-Hanger, N-NDI
15	Ambient Conditions		C-Controlled, U-Uncontrolled
16	Lighting Level		P-Poor, F-Fair, G-Good, E-Excellent
17	Noise Level		L-Low, M-Medium, H-High
18	Ancillary Equipment Eval.		P-Poor, F-Fair, G-Good, E-Excellent
19	Work Area Size		C-Cramped, M-Moderate, L-Large
***	Standard NDI Jobs Obtained from Standard Jobs Sheet		
20, 21	Ultrasonic	XX	Note 3
22, 23	Eddy Current		
24, 25	Penetrant		
26, 27	X-Ray		
28, 29	Leak Check		
30, 31	Magnetic Particle		

Figure 8-1. Facility Evaluation Punched Card Format

Figure 8-1. Facility Evaluation Punched Card Format (continued)

NOTE 1

Obtain Start and Completion dates from Daily Log. Start date is the date of the first day at the facility and the completion date is the date of the last day at the facility.

NOTE 2

Assume the following conditions for those data items which are incomplete.

Item 14 - G	17 - M
15 - C	18 - G
16 - G	19 - M

NOTE 3

XX - Percentage of total NDI jobs performed utilizing NDI Method

If an NDI method is not included or if there are no jobs listed after the method, then (ØØ) zeros will be "green sheeted" for the total number of jobs performed for that particular method.

COLUMN	DATA		FORMAT	REMARKS
1	Data Type (2)		X	
2, 3	Base ID		XX	
4	Date	Year	X	5, 6, 7 or 8
5, 6		Month	XX	Ø1 - 12
7, 8		Day	XX	Ø1 - 31
9		Day of Week	X	1-Sun; 2-Mon; ...; 7-Sat.
10	Inspection Location		A	1-Inside; 0-Outside
11	Temperature - indoor			L-Low; N-Normal; H-High
12	" - Outdoor			" " "
13	Precipitation			N-None; R-Rain; S-Sleet/Snow
14	Humidity			L-Low; M-Medium; H-High
15	Wind Velocity			" " "

Figure 8-2. Base Daily Punched Card Format

COLUMN	DATA	FORMAT	REMARKS
1	Data Type (3)	X	
2,3	Base ID	XX	
4,5	Instru. Mfr.	AA	Note 1a
6-9	Model	XXXX	Note 1b
10-14	S/N	XXXXX	Note 1c
***	Microvolts Deflection on Standard - Med. Range		
15-17	0.010"	XXX	Note 2
18-20	0.020	XXX	
21-23	0.050	XXX	

NOTE: 1

a) (Same as Note 3a Individual Inspection Log)

b) (Same as Note 3b Individual Inspection Log)

c) (Same as Note 3c Individual Inspection Log)

NOTE: 2

Maximum deflection with initial setting of 250 is therefore off scale or pegged condition to be coded as 999.

Figure 8-3. Equipment Performance [illegible] Current Punched Card Format

COLUMN	DATA	FORMAT	REMARKS
1	Data Type (4)	X	
2,3	Base ID	XX	
4,5	Instrument Mfr.	AA	Note 1a
6-9	Model No.	XXXX	1b
10-14	S/N	XXXXX	1c
15-16	Transducer Mfr.	AA	1a
17-20	Model	XXXX	1b
21-25	S/N	XXXXX	1c
26	Frequency	X	Note 2a
27,28	Angle	XX	Note 2b
***	Instrument Set-up		
29-31	Coarse Gain	XXX	Note 3a
32,33	Fine Grain	XX	
34,35	Reject	XX	Percent of Full Scale
36,37	Pulse Length	XX	Percent of Full Scale
38	Coarse Sweep Range	X	
39,40	Coarse Sweep Multiplier	XX	Note 3b
41,42	Fine Sweep (Velocity)	XX	
43,44	Horiz-Inter-Echo Spacing 1-2	XX	Percent of Full Scale
45,46	Horiz-Inter-Echo Spacing 2-3	XX	
47,48	Vert. Echo-Height #3	XX	
49,50	Vert. Echo-Height #8	XX	

Figure 8-4. Equipment Performance - Ultrasonic Punched Card Format

Figure 8-4. Equipment Performance - Ultrasonic Punched Card Format (continued)

NOTE: 1a, 1b, 1c (Same as Note 3a, 3b, 3c - Individual Inspection Log)

NOTE: 2

(a) 0 - Data not recorded

1 - 2.25 MH_z

2 - 5.0 MH_z

3 - 10.0 MH_z

(b) ANGLE in degrees such as 60° = 60.

00 - Date not recorded.

NOTE: 3

(a) Convert one and two digit numbers to three digits as follows:

One digit:	.1	001;	2	020
Two digits	0.1	001;	2.0	020

(b) Convert one digit numbers to two digits as follows:

.1 01; 2 20

COLUMN	DATA	FORMAT	REMARKS
1	Data Type (5)	X	
2,3	Base ID	XX	
***	X-Ray		
4,5	Equip. Mfr.	AA	NOTE 1a
6-11	Model No.	XXXXXX	1b
12-16	S/N	XXXXX	1c
17-18	Film Processor Mfr.	AA	1a
19-22	Model	XXXX	1d
23-27	S/N	XXXXX	1c
28-30	Stepped Wedge Nor. Exp. 1st Step	XXX	Relative Value
31-33	2nd		
34-36	3rd		
37-39	4th		
40-42	2X Exp. 1st Step		
43-45	2nd		
46-48	3rd		
49-51	4th		
52-54	Div. Tst. Strip-Density 1st Step		
55-57	2nd		
58-60	3rd		
61-63	4th		
***	Penetrant		
64, 65	Mfr.-Penetrant	AA	Note 1a
66	Penetrant Group	X	
67, 68	Developer - Mfr.	AA	Note 1a
69	Developer Type	A	A-Aqueous N-Non-Aqueous
70	Results	A	E-Excellent; G-Good; F-Fair; P-Poor

Figure 8-5. Equipment Performance - X-Ray & Penetrant Punched Card Format

Figure 8-5. Equipment Performance - X-Ray & Penetrant Punched Card Format (continued)

NOTE: 1a, 1c & 1d - (Same as NOTE 3a, 3c and 3b, respectively - Individual Inspection Log)

1b - Model Number - Six least significant digits of model number.

EX: 69150K - 69150K; 50 KVA - 050 KVA

COLUMN	DATA	FORMAT	REMARKS
1	Data Type (6)	X	
2-6	Assigned A/F ID No.	XXAXX	Note 1
7	Date - Year	X	5, 6, 7 or 8
8, 9	Month	XX	Ø1 - 12
10, 11	Day	XX	Ø1 - 31
12	Skill Level	X	Note 2
13	High School Grad.	X	N-No; Y-Yes Note 3
14	College	X	Ø-9 (Number of years completed)
15-17	NDI Training	XXX	Total Number of Hours Note 4
***	Job Experience		
18, 19	NDI	XX	Note 5
20, 21	Technical		
22, 23	Clerical/Managerial		
24, 25	Skilled		
26, 27	Other		
28, 29	Skilled/NDI		
***	Inspections performed per month on Engine (E) and Aircraft Structure (A/C) parts utilizing specified methods.		
30-32	Ultrasonic (E)	XXX	Note 6
33-35	" (A/C)		
36-38	Eddy Current Surface (E)		
39-41	" " " (A/C)		
42-44	EC-Bolt Hole, Man. (E)		
45-47	" (A/C)		
48-50	, Auto (E)		
51-53	" (A/C)		
54-56	Penetrant (E)	XXX	Note 6
57-59	" (A/C)		
60-62	X-ray (E)		
63-65	" (A/C)		
***	Physical Data		
66, 67	Height	XX	Ø - No Data Note 7
68-70	Weight	XXX	
71, 72	Age	XX	
73	Sex	X	M-Male; F-Female
74	Marital Status		M-Marr.; S-Single
75	Wear Glasses		Y-Yes; N-No
76	Physical Limitations		Y-Yes; N-None
77	Technician Evaluation	A	

Figure 8-6. Technician Profile Punched Card Format

Figure 8-6. Technician Profile Punched Card Format (continued)

NOTE 1

Assigned A/F Identification No.

a) Any Technician Profile Form which does not contain a valid ID number will be considered invalid and the data will not be "green sheeted".

Examples of valid ID numbers:

1) Four digit numbers: 0916, 0407, 03E8, 03U6
2) Five digit numbers: 03E12, 16U10, 16U2E
3) Six digit numbers: 16U10E, 16E11U

b) All ID numbers will be converted to a standard (5) five digit format. Four digit numbers will be converted by either

1) Inserting the letter 'B' between the second and third digits of those ID numbers containing four numbers - Ex: Ø916-Ø9B16; Ø4Ø7-Ø4BØ7

2) Inserting a zero between the third and fourth digits of those ID numbers containing three numbers and one letter: Ex: Ø3E8 - Ø3EØ8; Ø3U6 - Ø3UØ6

Five digit numbers containing three numbers and two letters will be converted by deleting the letter in the fifth digit and inserting a zero between the third and fourth digits. Ex: 16U2E - 16UØ2

Six digit numbers will be converted by deleting the letter in the sixth digit. Ex: 16U10E - 16U10; 16E11U - 16E11

NOTE 2

The single digit skill level number is derived from the Job Title or AFSC number. The AFSC number is a five (5) digit number with the fourth digit designating the skill level (XXX X X). Example: AFSC #531 5 5 designates a level 5 and AFSC #536 9 0 a level 9. The AFSC skill levels are: 3, 5, 7 and 9.

If an AFSC number is not provided, a skill level coded reference will be provided and will be recognized as the number or letter in parenthesis.

NOTE 3

Any of the following in the GRADUATE (Space) signifies a high school graduate: yes, (✓) check mark, year, GED, and No-GED. A 'no' or blank space signifies a non-graduate.

NOTE 4

Add the individual NDI training to obtain the total number of hours. 999 hours is the maximum hours which can be "green sheeted", therefore, when the total hours exceed 999 they will be "green sheeted" as 999.

Figure 8-6. Technician Profile Punched Card Format (continued)

NOTE 5

Job Experience is the total number of years a technician has worked in each job category.

A. Obtain NDI experience from Item 5 of the Technician Profile Form. Convert the months given to the nearest year using the following guideline: 0-5 Mos. = 0 Yr.; 6-12 Mos. = 1 Yr. and add to the years given to obtain the total number of years experience.

Ex: 9 Yrs. 5 Mths. - 9 Yrs.; 9 Yrs. 6 Months = 10 Yrs.

B. Item 6 (Job History) of Technician Profile Form.

1) Categorize each job into one of the five categories listed below. Use the examples of occupations as an aid in determining the proper category.

2) Delete those jobs associated with NDI.

3) Convert the From-To dates into the total number of years on each job.

Ex. From: Nov 73 To: Sept 75 = 2 Years
From: Nov 73 To: Jan 75 = 1 Year

4) Add the total number of years associated with each category and "green sheet".

Figure 8-6. Technician Profile Punched Card Format (continued)

JOB CATEGORIES

1. NDI

NDI (Specialist, Technician, Superintendent, Apprentice)
Skill
Industrial Radiographer
Ultrasonic Equipment Operator
Physical Science Technician

2. Technical

Technician
Engineer
Chemist
Laboratory Worker

3. Clerical/Managerial

Supervisor
Manager
Secretary
Typist
Operator, Radio
Operator, Teletype
Operator, Computer
Supply Clerk

4. Skilled

Mechanic
Machinist
Brick Layer
Carpenter

5. Other

Truck Driver
Laborer
Grocery Clerk
Salesman
Student
Serviceman (Army, Navy, etc.)

6. Skilled/NDI

A/C Sheet Metal Worker
Welder

Figure 8-6. Technician Profile Punched Card Format (continued)

NOTE 6

The maximum allowable number of inspections per month for "green sheeting" is 999. All inspections per month greater than 999 will be "green sheeted" as 999.

Ex: Penetrant (A/C)1250 - - 999

NOTE 7

All heights will be converted into inches before "green sheeting".

Ex: 5 ft. 11 inches = (5 x 12) + 11 = 60 + 11 = 71 inches.

COLUMN	DATA	FORMAT	REMARKS
1	Data Type (7)	X	
2-6	Technician ID	XXAXX	Note 1
7-11	Date Yr-Mo-Day	X XX XX	
12	Day of Week	X	1-Sun; 2-Mon; ...; 7-Sat.
13	Sample Type	A	'A' Sample A; ...; 'G' Sample G
14, 15	NDI Method	AA	Note 2
16, 17	Equipment Mfr.	AA	Note 3a
18-21	Model No.	XXXX	3b
22-26	Serial No.	XXXXX	3c
27, 28	Probe/Trans. Film Mfr.	AA	3a
29-32	Model/Type	XXXX	3b
33-35	Inspection Time	XXX	Note 4
***	Ultrasonic Method		
36	Transducer Frequency	X	Note 5a
37, 38	Transducer Angle	XX	Note 5b
***	Eddy Current Method		
39	Instrument Range Setting	X	Ø - Not recorded; L - Low; M - Medium; H-High
40, 41	Freq./Liftoff	XX	ØØ - 99 Note 6
***	Penetrant Technique		
42	Penetrant Group	X	Ø - Not Recorded (NR)
43, 44	Dwell Time Comparison	XX	Note 7
45	Application Method	X	Ø - NR; 1 - Spray; 2 - Brush
***	X-ray Technique		
***	Inspection Area Density Range/AIM		
46,47	Sample B-101	XX	Note 8a
48,49	-102		
50,51	-111		
52,53	-112		
54,55	-121		
56,57	-122		
58,59	-133		
60,61	-134		
62,63	-301		
64,65	-302		
66,67	-141		
68,69	-142		
70	Film Processing	X	Note 8b

Figure 8-7. Individual Inspection Log Punched Card Format

Figure 8-7. Individual Inspection Log Punched Card Format (continued)

NOTE 1 (Same as Note 1 Technician Profile)

NOTE 2

Abbreviate NDI Methods as follows:

EA - Eddy Current Bolt Hole - Automatic
EH - Eddy Current Bolt Hole - Manual
EO - Eddy Current - Overhead
ET - Eddy Current Surface
PT - Penetrant
RT - X-ray
UA - Ultrasonic - Automatic
UT - Ultrasonic

NOTE 3

(a) Equipment Manufacturer - First two letters of Manufacturer's name.
Ex: Branson - BR; Sperry - SP

(b) Model Number - Four least significant digits of a model number.
Ex: ED520 - D520; ZL-22A - L22A; 600 - 0600

(c) Serial Number - Five least significant digits.
Ex: 692445 - 92445; 0260 - 00260

Zeroes will be entered for any or all of above where no data is recorded.

NOTE 4

Inspection Time - Total minutes 000-999
000 - Data not recorded

Determination of Inspection Time

(a) determine the difference in each Start Stop time (hours and minutes)

Ex:	Start	Stop			
			1) 11 45	2) 15 10	* 1470
1)	0830	1145	- 08 30	-1245	-1245
2)	1245	1510	3 15		225

1) 3 hrs. 15 minutes
2) 2 hrs. 25 minutes

* Convert 15 10 to 14 70 by subtracting 1 hr (60 min) from 15 hr and adding the 60 min to 10 min = 14 70.

(b) Convert the hours to minutes and add to the existing minutes:

1) 3 hrs 15 mins = (3 x 60) +15 = 180 + 15 = 195 minutes
2) 2 hrs 25 mins = (2 x 60) + 25 = 120 + 25 = 145 minutes

Figure 8-7. Individual Inspection Log Punched Card Format (continued)

(c) Sum the individual inspection times

1) 195 min.
2) +145 min = 340 minutes INSPECTION TIME

NOTE 5

a) Ø - data not recorded
2 - 2.25 MHz
5 - 5.0 MHz
9 - 10.0 MHz

b) ANGLE in degrees such as 60° = 60.
ØØ - data not recorded

NOTE 6

00 - no data recorded

Convert single digit numbers to two digit by adding a zero preceding the number.
Ex: .9 - 09.

Convert three digit numbers to two digits by deleting the third digit and rounding.
Ex: 2.25 - 23; 1.13 - 11.

NOTE 7

Dwell times - Penetrant and Developer

This data item compares the dwell times specified in the test procedure with the actual dwell time recorded by the technician. A variation of plus or minus (5) minutes or more will be coded as below.

TEST PROCEDURE DWELL TIME:

Penetrant 20 minutes; Developer 20 minutes.

Ø - data not recorded
1 - required dwell time (RDT)
2 - under RDT
3 - over RDT

Ex: Dwell time data: Penetrant - 18 min. Developer - 15 min.
Coded - 1 2

NOTE 8

a) 1st digit - x-ray film density range
2nd digit - x-ray tube aim
(obtain from Inspection Result Score Sheet)
Ø - no data recorded

Figure 8-7. Individual Inspection Log Punched Card Format (continued)

b) Ø - no data recorded
1 - automatic processing
2 - hand processing

* X-ray - measured film density range vs specified normal density range and estimate aim of x-ray beam.

Density Range:

Ø - both low and high values within range
1 - both low and high values out of range
2 - low value in and high value out of range
3 - high value in and low value out of range

AIM:

Ø - centered
1 - off center

COLUMN	DATA	FORMAT	REMARKS
1	Data Type (8)	X	
2-6	Tech ID	XXAXX	Note 1
7	Sample Type	A	Note 2
8, 9	NDI Method	AA	Note 3
10	Date - Year	X	
11, 12	- Month	XX	
13, 14	- Day	XX	
15, 16	False Find	XX	Total Number
17, 18	Ratio Find - Opportunities	XX	Percent
19	Flawsite Results	X	Note 4
n			

n = Total number of flawsites in Sample.

Figure 8-8. Inspection Results Punched Card Format

Figure 8-8. Inspection Results Punched Card Format (continued)

NOTE 1 (Same as Note 1 Technician Profile)

NOTE 2 Sample 'A' - A; Sample 'B' - B; ...; Sample 'G' - G
Sample 'G' contains 123 flawsites, therefore a second inspection results data card will be required. The second card will contain Flawsite Results and will be a continuation of columns 19. - n .

Sample	Flawsites	Sample	Flawsites
A	42	E	27
B	52	F	43
C	41	G	123
D	10		

NOTE 3 (Same as Note 2 Individual Inspection Log)

NOTE 4

Use Inspection Results Score Sheet

a) A check mark in the Find or Miss column of the score sheet is denoted by a (0) Zero for a Miss and a (1) One for a Find.

b) A dash mark or blank space in the Find and Miss columns indicate a flawsite which was not inspected. This is denoted with a (2) two on the "green sheet"

0 - Miss
1 - Find
2 - Flawsite not examined.

COLUMN	DATA	FORMAT	REMARKS
1	Data Type (9)	X	
2	Sample Type	A	'A' - Sample A; ...; 'F' - Sample F
3,4	Flaw Size	XX	Note 1
↓	↓	↓	
79,80		XX	

NOTE 1

Flaw size is represented by two digits, therefore all three and four digit numbers will be converted to two digits.

Ex: 0.020 = 02; 0.015 = 02
0.185 = 19; 0.020 = 02

The two flaws which are greater than (1) inch in length will be coded as follows:

1.05 inches = 95
1.95 inches = 99

Figure 8-9. Flaw Size Tabulation Punched Card Format

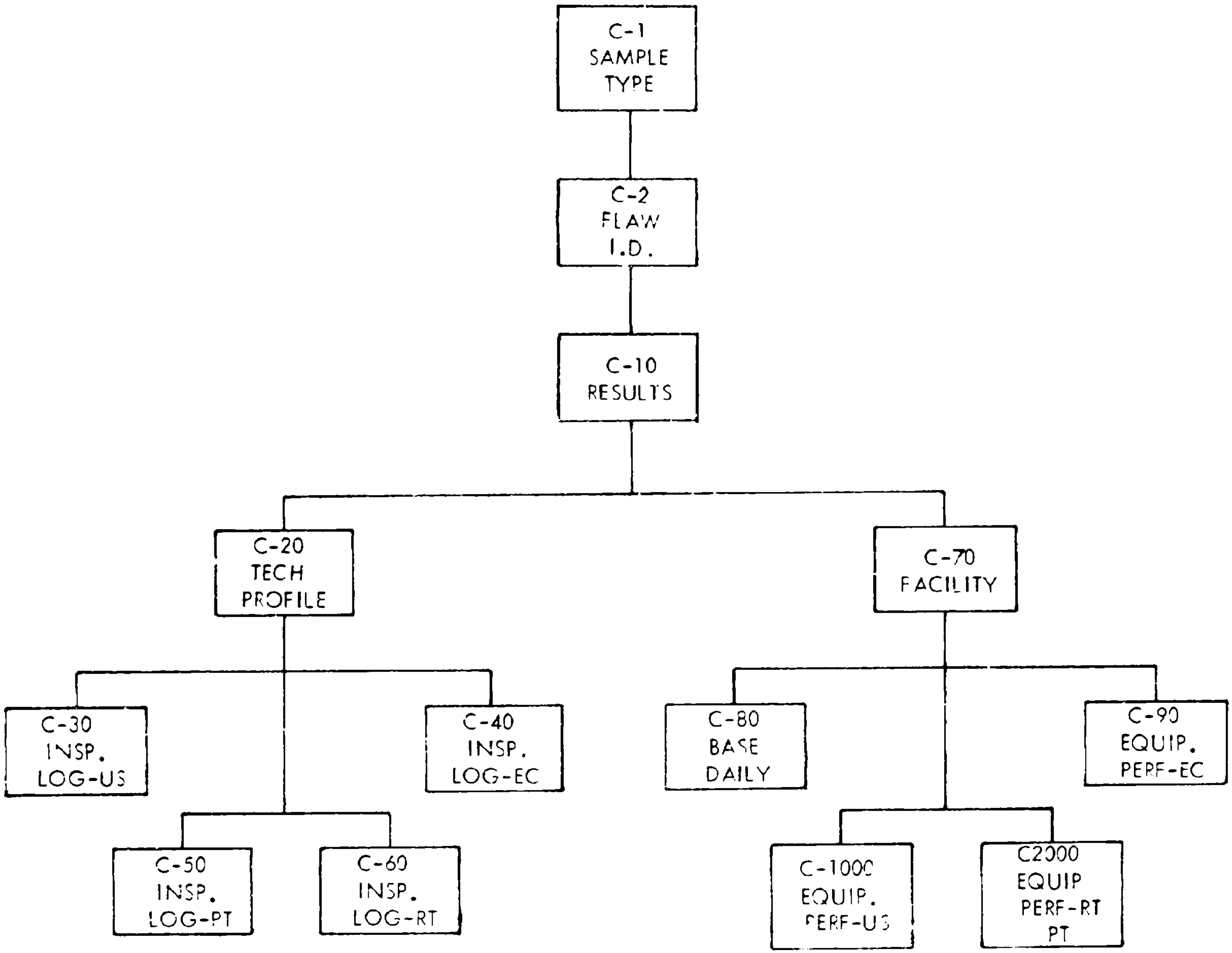


Figure 8-10. Schematic of the System 2000 Data Base Definition, with Assigned Hierarchical Numbers or Indices

DESCRIPTOR INDEX	DATA CATEGORY
1	Sample-Type
2	Flaw-ID
3	Flaw-Serial
4	Flaw-Radial-Length
5	Flaw-Bore-Length
6	Flaw-Area
7	Flaw-Angle-Alpha
8	Flaw-Angle-Beta
9	Flaw-Type
10	Result-Rec
100	NDI-Method
101	Base-ID
106	Technician-ID
102	Result-Date
103	Result
104	False-Find
105	Ratio-Find
107	Command
20	Technician-Profile
203	Date
204	Skill-Level

Figure 8-11. Data Base Definition Sample

SECTION IX. ANALYSIS METHODOLOGY

This NDI Reliability Program was planned to comprehensively measure NDI performance in the setting where daily work is normally conducted in field and depot shops. As such, a number of observations were necessarily performed on many variables to document conditions surrounding the NDI processes. Analyses of the program results may be therefore viewed in terms of NDI performance in flaw detection and false calls relative to a variety of possible categories. A schematic of data combinations available for analysis is depicted in Figure 9-1. General categories of location, environment, participant capabilities, equipment performance and structure type, combined with the NDI method, yield a performance of flaw find/no find and false calls. Each general category of the data has intrinsic features which allow for a number of subdivisions which will be discussed in a following section on Fundamental and Secondary Variables. In all cases, the central issue is detection performance on fatigue cracks with given characteristics.

Acquisition Format

The general categories for data acquisition which were defined in the planning phase of the program are as follows:

1. Inspection results in terms of flaw finds, no finds, and false calls

2. Individual inspection logs containing date and time of day, equipment used, and NDI operating parameters

3. Technician profiles which characterized participant background and physical data

4. Base daily logs with weather and task assignment information

5. Facility evaluations concerning the shop and working conditions

6. Equipment performance checks which measured the operating ranges of equipment

7. Tabulation of flaw lengths and characteristics

The last item, 7, was actually completed with estimated flaw lengths in the planning phase and was used in conjunction with Item 1, in the initial performance evaluations.

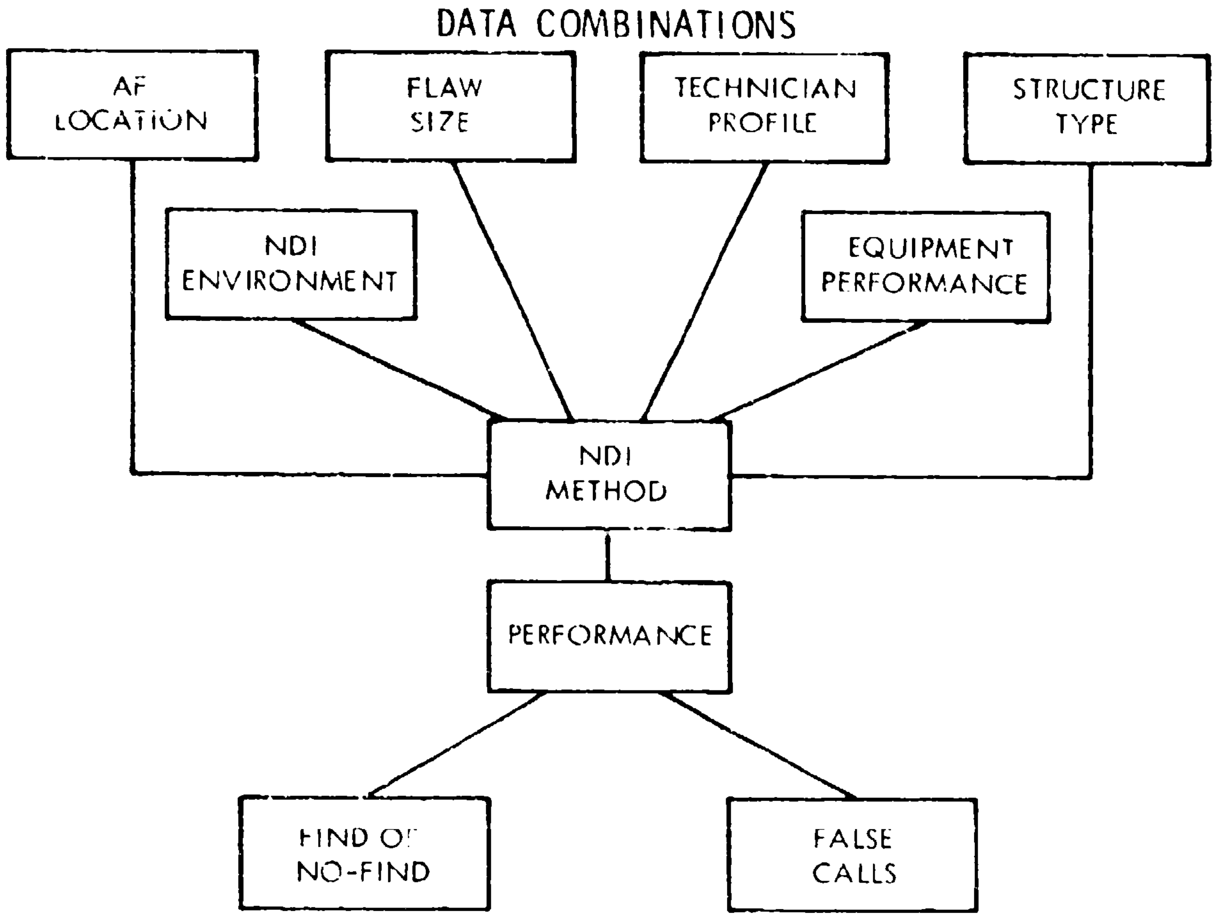


Figure 9-1. Schematic of General NDI Data Categories

Quantitative results are sought in the data reduction and evaluation. A convenient format for performance evaluation is either a curve or histogram of flaw detection probability relative to flaw size (flaw length, a major factor in its size considerations, is commonly used as a measure of flaw criticality).

A second aspect of performance evaluation is a test for significance of variables. This significance test answers the question of whether observed differences in flaw detection among different combinations of variables are attributed to those variables or to chance. The analyses in this effort, therefore, are planned to not only present results with a number of histograms or curves identified by a given set of variables, but to also quantify the significance of any differences between those results which are selected by given variable sets.

Fundamental and Secondary Variables

The fundamental set of variables that have been recorded in this program are as follows:

a. NDI Method
b. Structure Sample Type
c. The Dare of Inspection
d. Participant Identification Number
f. Distinction Between Field or Depot
g. Flaw Identification Number
h. Flaw "Find" or "No Find"
i. False Calls by Participant Identification Number

A more complex set of secondary variables, which interrelate with the fundamental set, have also been recorded. They are listed by type as follows:

A. Technician Profile

i) skill level
ii) education level
iii) amount of formal NDI training
iv) job history
v) NDI work pace (inspection tasks per month)
vi) physical data

B. Flaw Character

i) flaw length
ii) flaw area
iii) aspect ratio
iv) orientation with respect to the inspection surface

C. Inspection Log

i) equipment identification
ii) operating parameters
iii) task assignment (sample type and NDI method)
iv) day of week

D. Environment/Facilities

i) shop type
ii) ambient conditions
iii) weather
iv) work area description
v) lighting and noise level
vi) equipment performance

Many combinations of variables have been observed in the course of data acquisition; some are significant and some are not. Subsequent statistical treatments of the recorded data will reveal which variables warrant attention.

Graphic Treatment of Variables

Preliminary analysis procedures which were designed at the outset of data acquisition phase yielded composite histograms of mean detection probabilities for flaw size ranges encompassing an average of seven individual flaw lengths as shown in Figure 9-2.

The seven point grouping was arbitrarily selected as the one most convenient for viewing the pattern of results where grouping the data was necessary to obtain a sufficient sample size to calculate confidence bounds as described in Section 3. As the data acquisition progressed, the number of individual attempts to find each flaw was sufficient to develop analytical approximations of detection probabilities relative to flaw lengths as shown in Figure 9-3. These approximations evolved by examining a number of transformations of the variables to select those which minimize scatter about an estimated mean. A reasonably good analytical fit was observed with the following transformations:

$$x = 1/a_c \qquad (1)$$

$$y = [\ \ln\ 1/p\ ] / a_c, \text{ where } \ln = \log_e \qquad (2)$$

where a_c = the flaw size parameter and p = the point estimate of the detection probability. For example, a fatigue crack of radial length a_c = 0.30 inches has been detected by eddy current scans 72 times out of 90 attempts to yield a point estimate of the probability, p = 0.80.

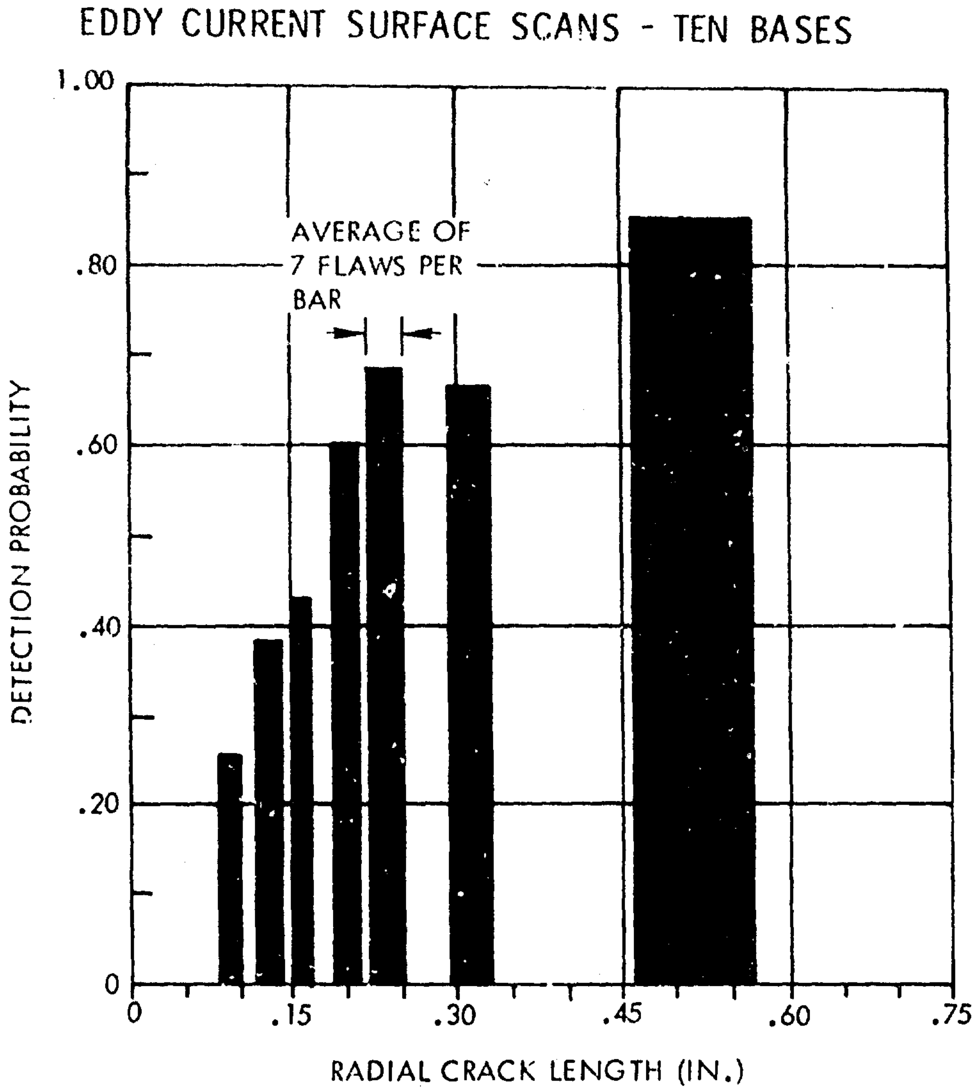


Figure 9-2. Typical Histogram Presentation of Flaw Detection Results

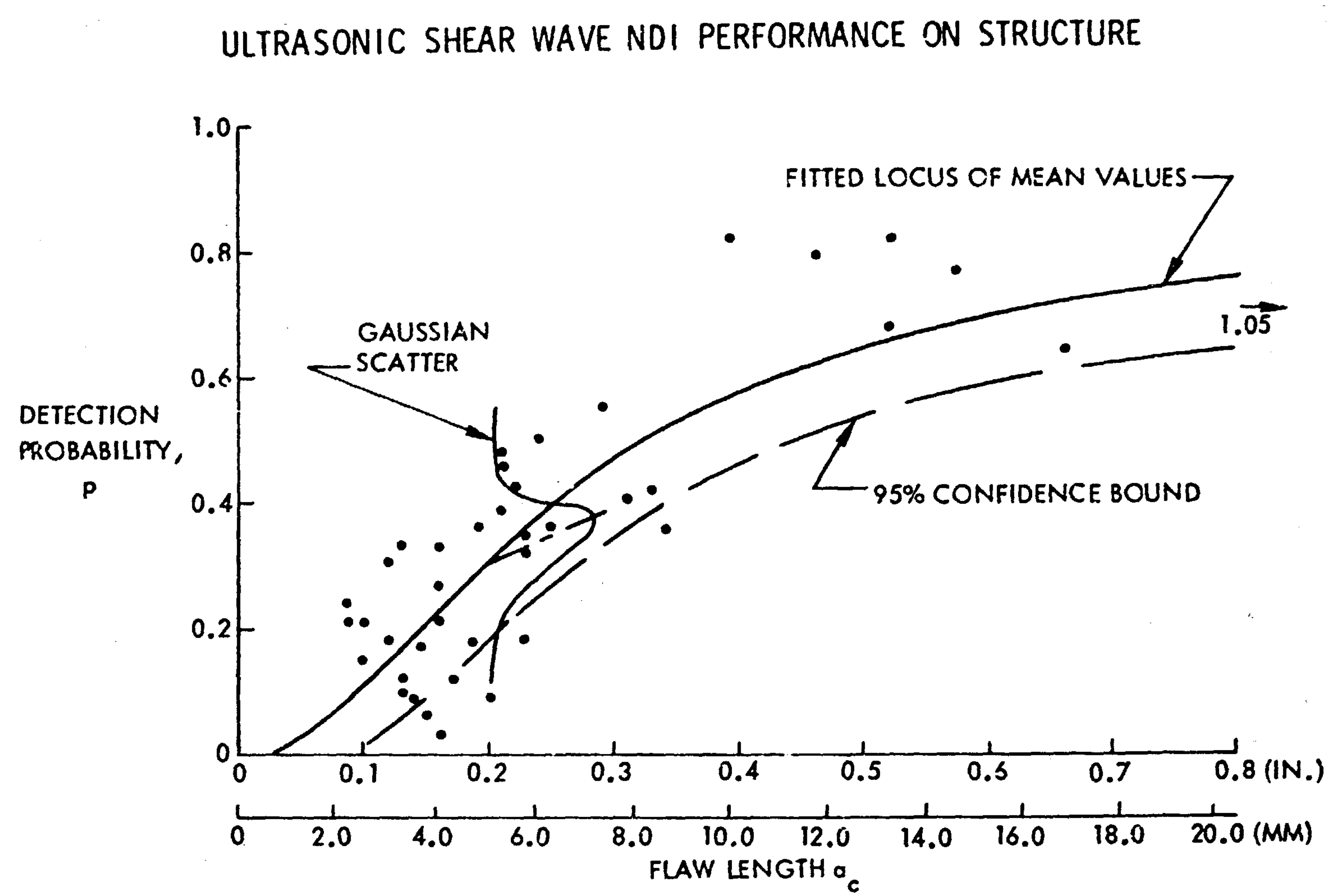


Figure 9-3. Example of Curve Fit to Flaw Detection Point Estimates

The trend of the transformed variables was then correlated to a generic expression:

$$y = a\,(x)^b \tag{3}$$

where a and b are constants determined by a power curve fit to the data as follows:

$$b = \frac{\Sigma (\ln x_i)(\ln y_i) - \dfrac{(\Sigma \ln x_i)\,(\Sigma \ln y_i)}{N}}{\Sigma (\ln x_i)^2 - \dfrac{(\Sigma \ln x_i)^2}{N}} \tag{4}$$

$$a = \exp\left[\frac{\Sigma \ln y_i}{N} - b\,\frac{\Sigma \ln x_i}{N}\right] \tag{5}$$

N = the total number of data points or point estimates used to establish the curve.

The coefficient of determination for the power curve fit to the data is given by:

$$r^2 = \frac{\Sigma (\ln x_i)\,(\ln y_i) - \dfrac{(\Sigma \ln x_i)\,(\Sigma \ln y_i)}{N}}{\left[\Sigma (\ln x_i)^2 - \dfrac{(\Sigma \ln x_i)^2}{N}\right]\left[\Sigma (\ln y_i)^2 - \dfrac{(\Sigma \ln y_i)^2}{N}\right]}$$

Combining equations (1) and (2) into (3), with the inverse transformation, yields the expression:

$$\hat{p} = \exp\left[-a\,(1/a_c)^{b-1}\right] \tag{7}$$

where $\hat{p}$ = the estimated average detection probability.

Scatter and Confidence Limits

The success or failure to detect a flaw by a number of independent trials, as exercised in the data acquisition, should exhibit a binominal character described in the following treatment. Given a probability of success = p and a failure probability = 1-p for n independent trials, then the probability of success s in n such trials is expressed by:

$$p(s) = \begin{bmatrix} n \\ s \end{bmatrix} p^s \; (1 - p)^{n-s} \qquad (8)$$

where s is the observed number of successful detections. This implies that each measured point estimate p is an average value representing a binomially distributed scatter of values. The variance V_1 which quantifies this scatter is expressed by:

$$V_1 = [\hat{p}\,(1-\hat{p})]/n \qquad (9)$$

where n = the total number of attempts to detect the flaw. In actuality, the scatter which is intrinsic to each point estimate is graphically displayed in Figures 9-4 through 9-7.

Detection performance on flaws within the denoted length ranges are shown for a 37 participant group. If the flaw detection process is strictly mechanistic; i.e., not subject to human factors, the group response would be characterized by a binomial statistic which is illustrated on each performance histogram. However, the measured performance exhibits the influence of human factors which has a bimodal character; an inhomogeneous group of participants.

The second contribution to scatter lies in variability of the flaw character. Flaws of nearly identical lengths are not detected with the same degree of success. The variance V_2 attending this source can be directly evaluated by:

$$V_2 = \frac{1}{N} \Sigma (\hat{p} - p)^2 \qquad (10)$$

where N = the total number of point estimates and $\hat{p}$ = the analytical estimate of p. The total variance is the sum of the two sources expressed by:

$$V = V_1 + V_2 = [\hat{p}\,(1-\hat{p})]/n + \frac{1}{N} \Sigma (\hat{p} - p)^2 \qquad (11)$$

Confidence bounds attached to the trend information can be approximated by assuming a normal distribution of contributions to the [illegible] variance V. This assumption is permissible if the following condition, described in Reference 11, is met:

$$np > 5 \text{ and } n\,(1-p) > 5 \qquad (12)$$

for the binomial component of the variance V_1. Additionally, the flaws within a given size range exhibit an approximately normal probability distribution about the estimate of the mean; which implies that con[illegible]ibutions to V_2 are Gaussian.

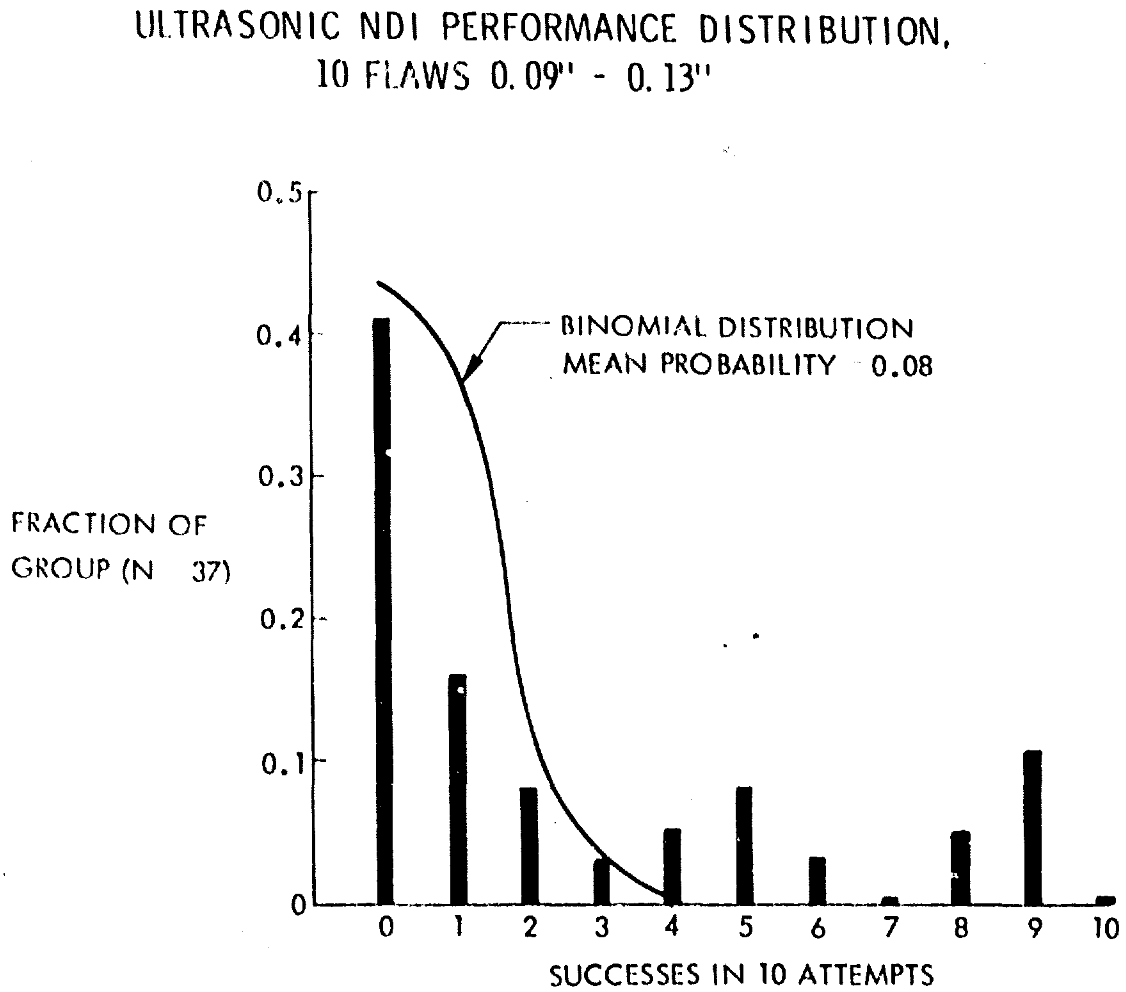


Figure 9-4. Performance Distribution on a Difficult Flaw Detection Task

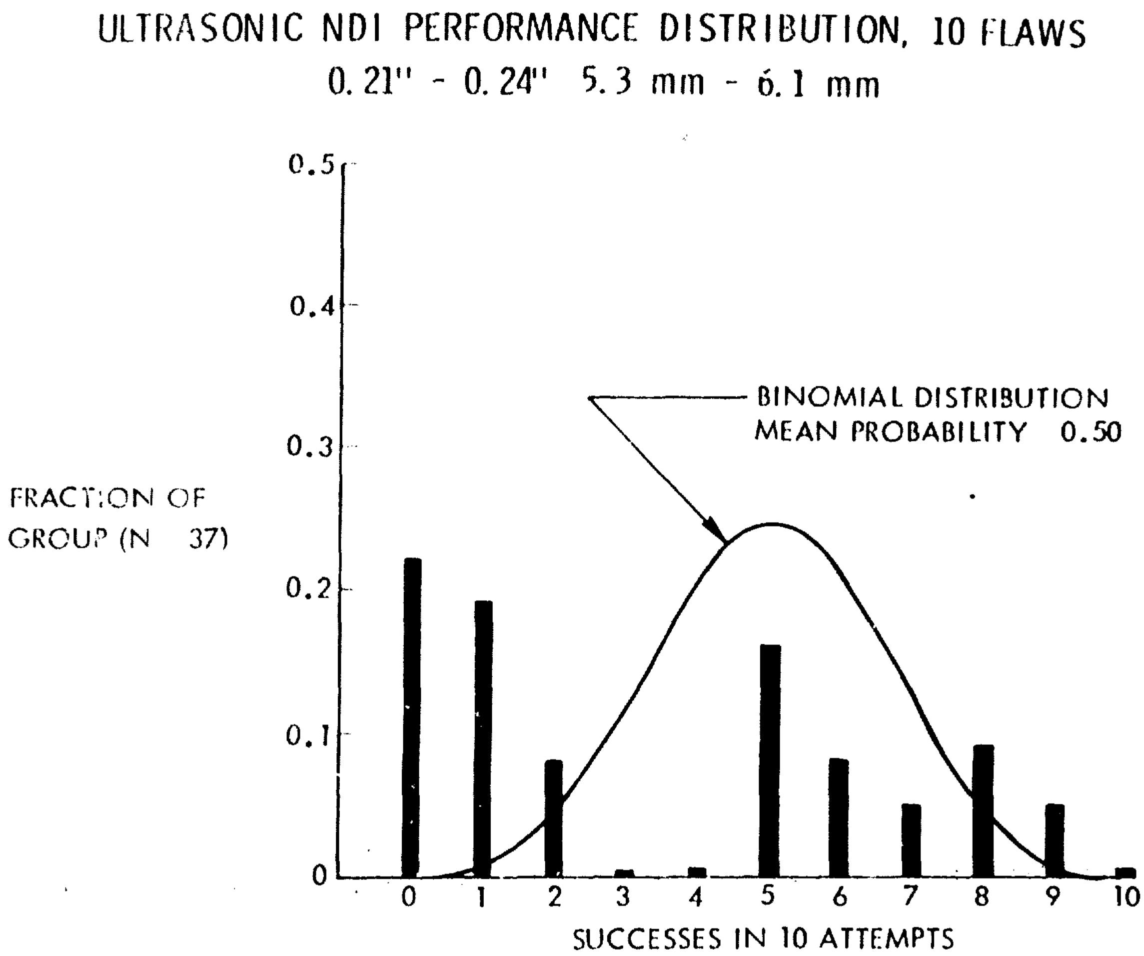


Figure 9-5. Performance Distribution on a Moderate Flaw Detection Task

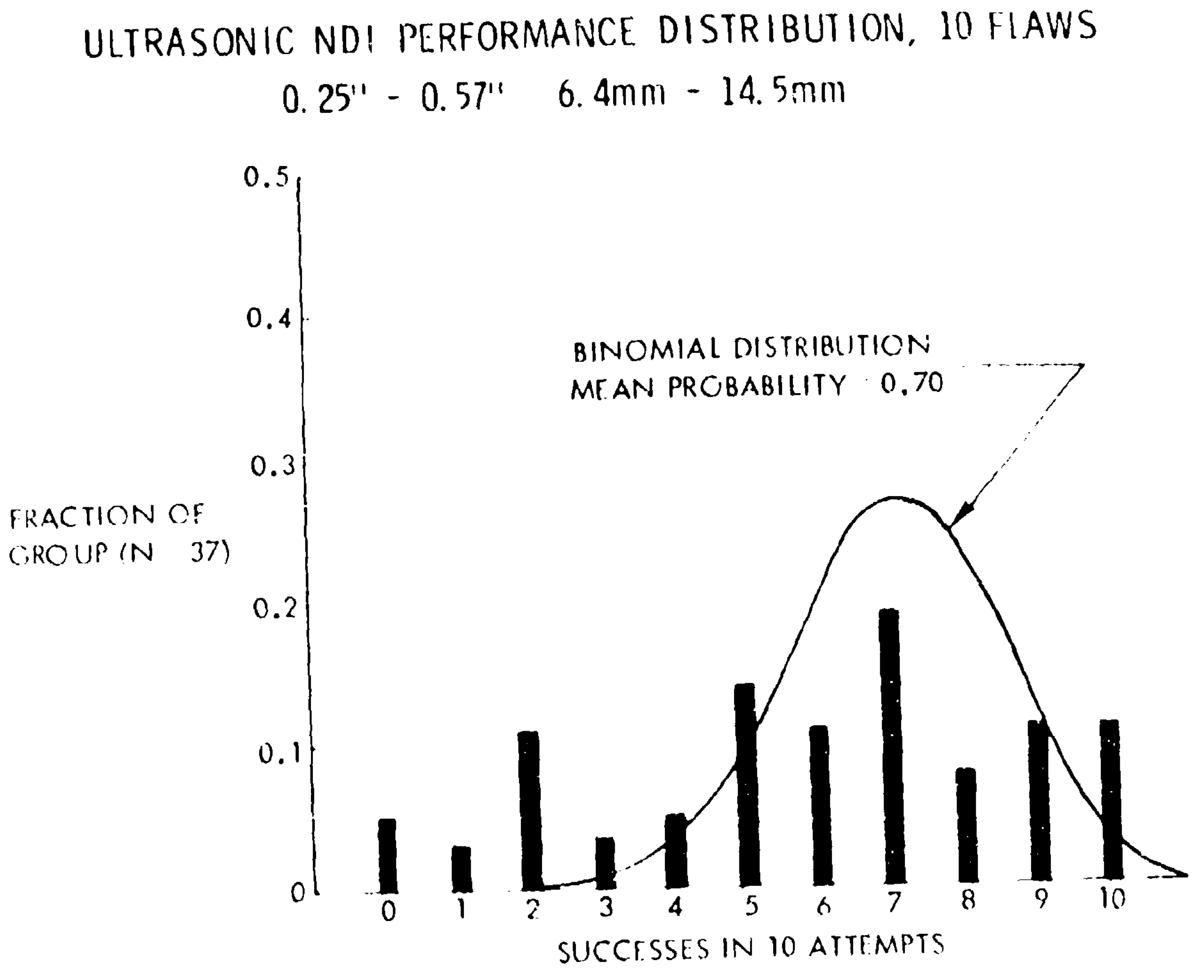


Figure 9-6. Performance Distribution on an Easy Flaw Detection Task

ULTRASONIC NDI PERFORMANCE DISTRIBUTION, 5 FLAWS

0.39" - 0.57" 9.9mm - 14.5mm

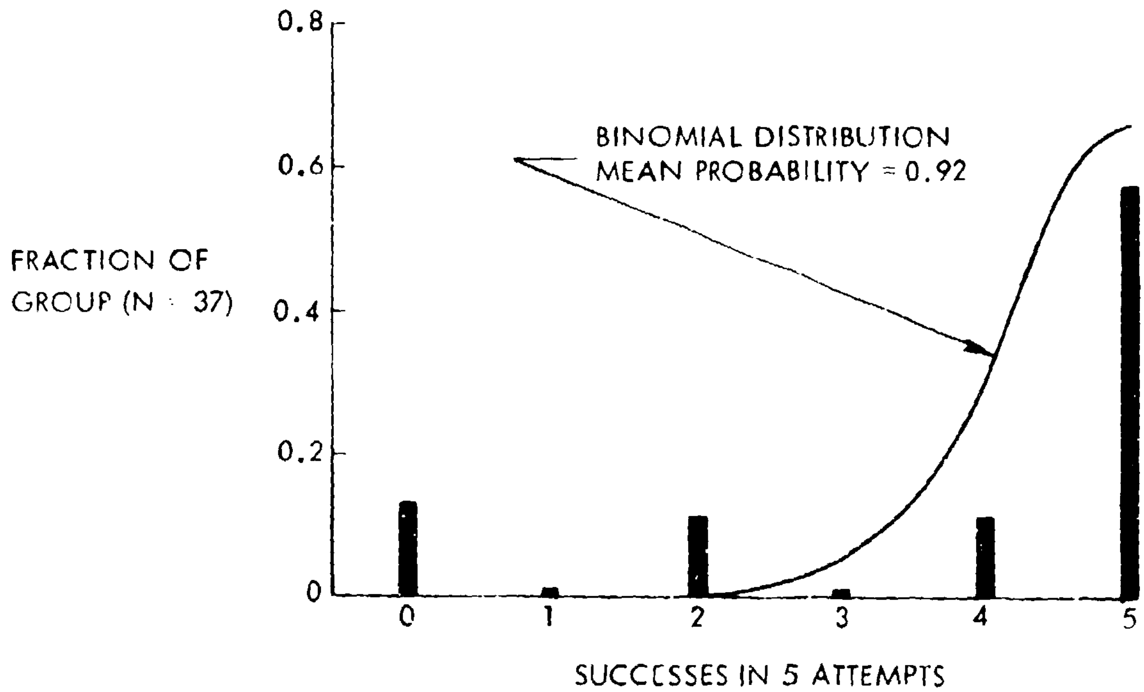


Figure 9-7. Performance Distribution on a Very Easy Flaw Detection Task

Although it has been pointed out that V_1 is not truly binomial, the combined influence of V_1 and V_2 can be reasonably treated by Gaussian multipliers t_α to determine confidence bounds as follows:

$$p_\alpha = \exp \left[-a \left(1/_{a_c}\right)^{b-1} \right] - t_\alpha \left[\hat{p}\,(1-\hat{p}) \,/\, n + \frac{1}{N} \Sigma (\hat{p}-p)^2 \right]^{1/2} \qquad (13)$$

where t_α values are assigned for selected levels of confidence shown in Figure 9-8 (Reference 13).

Level of Confidence	t_α
0.50	0
0.90	1.29
0.95	1.65
0.99	2.33

Figure 9-8. Gaussian Multipliers for Selected Levels of Confidence

Tests for Significance

A product of the preliminary analyses was the test for significance of selected variables. The variables of flaw size in four length groups, NDI method, participant and test site or location were examined for significance conducted early in the data acquisition phase are provided in Figure 9-9. The significance of flaw size (estimated length) was shown to be very great, as would be expected. The NDI method was also evidenced as a significant variable in the total scheme of flaw detection. Variance attributed to differences among participants (technician variable) at the field level were insignificant. However, the differences among participants at depots was significant.

These tests for significance were performed on variance ratios calculated from the division of variances by the residuals* for a given set of four variables. A schematic of the calculation sequence is depicted in Figure 9-10. The data acquisition and method of analysis in testing for significance were patterned after a factorial** ex-

* The residuals are the differences of the actual observations and a regression quantity based on the associated second variable in a covariance analysis.

**A design where all factors are varied simultaneously, as contrasted to a design which allows only one factor to vary while the remaining ones are held constant.

SIGNIFICANCE OF PARAMETERS

Test Parameter	Depot NDI (Variance Ratio)	Significance Value ("F" Ratio)	Comments	Field NDI (Variance Ratio)	Sign. Value ("F" Ratio)	Comments
Flaw Size	15.116	2.6049	Highly Significant	21.726	2.6049	Highly Significant
NDI Method	10.636	2.2141	Highly Significant	26.857	2.2141	Highly Significant
Technician	2.8364	1.9384	Significant	1.8783	3.5	Not Significant
Parameter Interactions						
Flaw Size/ NDI Method	2.6317	1.6664	Significant	6.5768	1.6664	Highly Significant
Flaw Size/ Technician	2.8208	1.5173	Significant	.97711	1.0	Not Significant
NDI Method/ Technician	1.3079	1.3940	Not Significant	2.1150	1.0	Significant
Flaw Size/ NDI Method/ Technician	0.57387	1.2214	Not Significant	.78966	1.0	Not Significant

Figure 9-9. Tests for Significance of Variables Conducted Early in the Program from 1 Depot and 3 Field Installations. The "F" Ratio is that Value which Reflects Variance due to Randomness

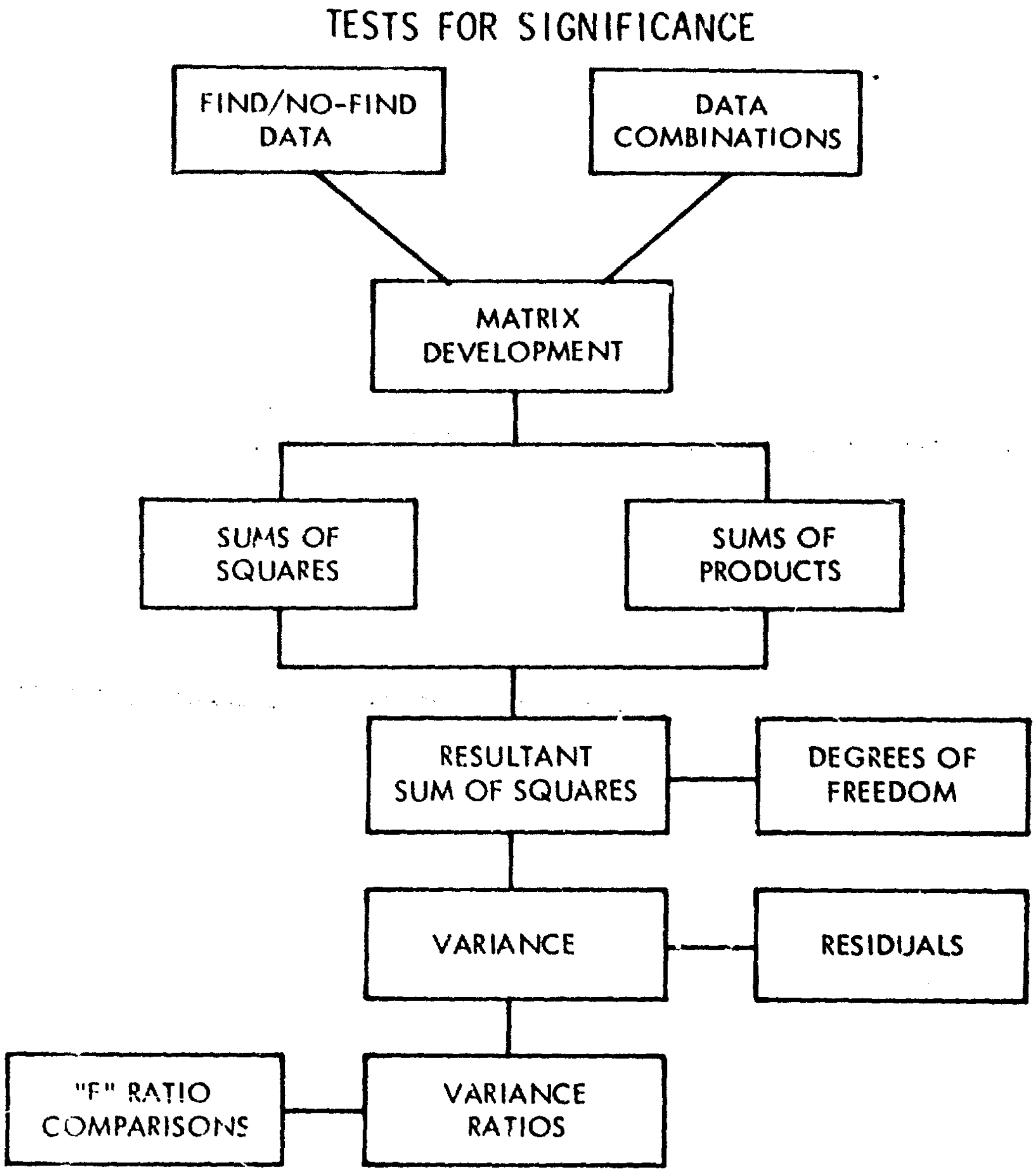


Figure 9-10. Calculation Sequence for Statistical Tests for Significance

perimental design. The matrix depicted in Figure 3-1 shows basic combinations of structure type and NDI methods. This matrix can be extended to encompass any number of variables in theory, but was limited to four in this analysis. The tests for significance treated the four variables of flaw size, NDI method, technician and site. Other combinations could be day of week, time of day, technician age and skill level, for example. Some given sets of variables such as those paired in Figure 3-1, will have missing combinations. This particular set of variables exhibits blanks in the matrix (non-orthogonal data) because not all structure types are inspected by all NDI methods. An incomplete matrix situation can be handled by a scheme for treatment of non-orthogonal data. Goulden [12] has devoted a chapter to this in his text on "Methods of Statistical Analysis."

The missing value treatment is based on substituting dummy values into a covariance analysis scheme with master variables S and X. The S master variable represents original values for the flaw detection data acquired and the X master variable represents missing data. Where values in S exist, the assigned value of X = 0, and where no values of S exist, the assigned value of X = -1 is used. The original analysis scheme contained eight variables defined in Figure 9-11.

Code Symbol	Variable	Range
Q	Test Site	Depot or Field
P	Technician Skill Level	Three Levels
N	Sample Type	Six Structure Types
M	Inspection Type	Overhead or Below
L	Test Site	Twenty-Two Locations
K	Technician	Participants Per Site
J	NDI Method	Seven
I	Flaw Size Class	Four

Figure 9-11. Variables Included in Original Analysis Scheme to Test for Significance

Symbolically, the variables are expressed as:

$$S(QPNMLKJI) \text{ and} \tag{14}$$

$$X(QPNMLKJI) \tag{15}$$

composing an eight dimensional matrix array in each case.

As previously noted data processing has been limited to simultaneous treatment of four of the eight variables because of matrix complexity. Calculations for the covariance analysis follow the standard format of algebraic solutions to obtain variance ratios, except that each master variable is an array of individual variables. Data pooling is performed on the arrays in selected combinations to operate on only those variables of concern in the immediate analysis. An example of pooling to treat three variables is symbolically presented in the following expression:

$$SQ(PNM) = \sum_{1}^{Q_{max}} S(QPNM) \tag{16}$$

where Q_{max} = the value of Q for which real values of S(QPNM) exist. Similarly, the second and third level reductions are accomplished by using the following expressions:

$$SQP(NM) = \sum_{1}^{Q_{max}} \sum_{1}^{P_{max}} (QPNM) \tag{17}$$

$$SQPN(M) = \sum_{1}^{Q_{max}} \sum_{1}^{P_{max}} \sum_{1}^{N_{max}} (QPNM) \tag{18}$$

The complementary arrays in X are treated in the same manner. The calculations of variance ratios are performed by the expressions:

Sums of squares in primary arrays $\sum s^2 = S^2 - \left(\frac{\sum S^2}{N}\right)$ (19)

Sums of squares in complementary arrays $\sum x^2 = \sum X^2 - \left(\frac{\sum X^2}{N}\right)$ (20)

Sums of array products $\sum sx = \sum SX - \frac{\sum S \sum X}{N}$ (21)

Resultant sums of squares $\sum z^2 = \sum x^2 - 2b \sum sx + b^2 \sum s^2$ (22)

where:

$$b \quad \frac{\sum sx}{\sum s^2} \tag{23}$$

which is the regression coefficient.

Residuals are determined from total sums-of-squares minus the contributions to sums-of-squares from each variable and combination of variables. Variances are calculated by dividing the resultant sums-of-squares by their associated degrees of freedom and the variance ratios are determined by dividing these by the residual variance. Comparisons of the variance ratios to "F" ratios, which represent variability attributed to chance, yield tests for significance.

Comprehensive Analysis

The comprehensive analysis of data acquired in this effort is a computerized performance evaluation shown schematically in Figure 9-12. A data management system for filing and retrieving information is employed with processing subroutines for curve plots, histograms and tests for significance. Analyses are aimed at examining the most apparent relationships which consist of the following:

1. Graphic Plots - Flaw length versus probability of detection

   1-1 By NDI Method and Structure Type, All Technicians

      1-1.1 Upper 50%, 25%, 10% and 5% performers

      1-1.2 By technical job experience (5 categories)

      1-1.3 By field and depot categories

      1-1.4 By each day of the week

      1-1.5 By technician skill level

      1-1.6 By technician education level

      1-1.7 By technician age

      1-1.8 By technician NDI years of experience

      1-1.9 By technician NDI training hours

      1-1.10 By weather conditions

      1-1.11 By base

      1-1.12 By commands

PERFORMANCE EVALUATION

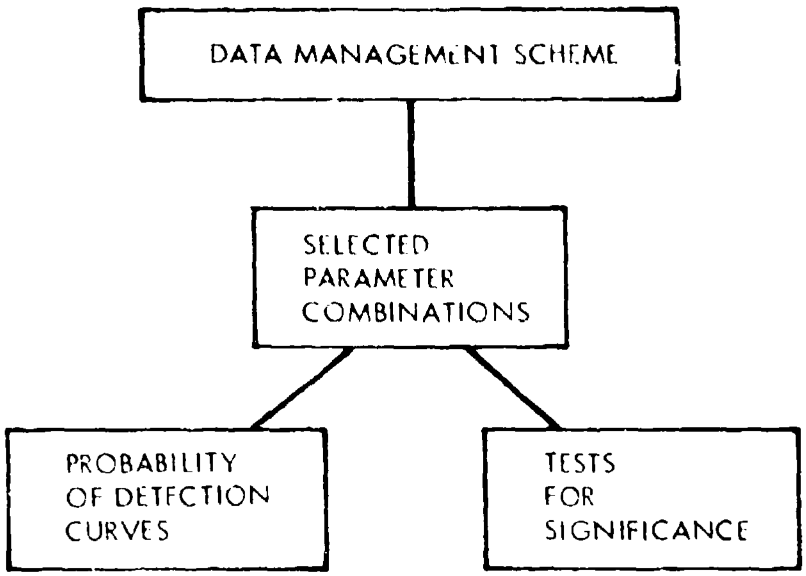


Figure 9-12. Comprehensive Data Analysis Scheme

II. Tests for Significance - Base composite performance

II-1. By NDI Method, all structure types

II-1.1 By NDI method, by structure type

II-1.2 By NDI method, by structure type, by equipment performance

II-2. By shop type

II-3. By work area conditions

II-4. By light level

II-5. By noise level

II-6. By standard jobs

II-7. By weather conditions

II-8. By equipment parameters

III. Probability of Detection versus:

III-1.1 Flaw identification number (ranking)

III-1.1 Flaw identification number by NDI method

III-1.2 Flaw identification number by flaw area

III-1.2.1 Flaw identification number, by flaw area, by NDI method and sample type

III-1.3 Flaw identification number by flaw aspect ratio

III-1.3.1 Flaw identification number by flaw aspect ratio, by NDI method and sample type

III-1.4 Flaw identification number by flaw surface position

III-1.4.1 Flaw identification number by flaw surface position, by NDI method and sample type

III-1.5 Flaw identification number by flaw plane angle to surface

III-1.5.1 Flaw identification number by flaw plane angle to surface, by NDI method and sample type

IV. Individual Performance Distributions

IV-1. By NDI method, by structure type, by flaw length

Combinations within parameter Group I provide an examination of effects due to technician background and base location influences. The comparisons within parameters Group II relate performance to environment and equipment, those in parameter Group III examine peculiarities of the flaws themselves, and those in parameter Group IV reveal the impact of human factors. Detailed analyses and graphic presentations of results are provided in Sections X and XI.

SECTION X. OVERALL NDI RELIABILITY FINDINGS

This section presents overall flaw detection capabilities observed in this program. The data are inclusive for all participants and it is cautioned that generalizations not be made from these overall Air Force results. Translation to specific sets of conditions will require judgment based on extensive NDI experience. Detailed analyses with regard to selected variables, in addition to NDI method and structure sample type, are provided in Section XI.

Probabilities of fatigue crack detection relative to flaw length in the structure samples examined by NDI in this program are graphically plotted in Figures 10-1 through 10-13. These plots display aggregate detection probabilities established by a large number of independent attempts to find the flaws. Each attempt was conducted by an individual who was selected by Air Force management to participate in this effort. A total spectrum of proficiencies among participants was requested at the outset of the data acquisition and the results bear this out. The plots represent measurement under documented sets of conditions by given NDI methods on specific structural configurations.

The curves are regression fit to the point estimates, as described in Section IX. Each curve is accompanied by the regression coefficients (a, b) and coefficient of determination (r), which indicates the "goodness" of fit (1.0 maximum). Lower 95% confidence bounds are provided to depict the combined effect of data scatter and sample size on the uncertainty in the measurements.

Characteristics of Results

The curves which estimate detection probability relative to flaw length are distinguished by their slopes and maxima within the depicted flaw length ranges. The ideal curve shape, in a limiting case, would be a step function which transitions from 0 to 1.0 detection probability over an infinitely small flaw length range. Such a transition would mean that no "gray area" exists; all flaws above a threshold length are detected. On the other hand, a gradual transition from low-to-high detection probabilities over a wide flaw length range would be far from ideal because judgment must be exercised concerning the large "gray area". This effort has produced data which exhibit curve shapes which range broadly within the spectrum from step function to gradual transition characteristics.

Eddy Current Surface Scans, Sample A, Figure 10-1

This curve depicts flaw detection characteristics for eddy current surface scans around countersunk fastener heads in the cover (skin) of an intact wing box section. The NDI task is performed with access to the inspection area approached from the upper surface. The mean results show a reasonably steep slope in the 0.10" to 0.30" radial length range and a continuing rise in the trend at the maximum.

Ultrasonic Shear Wave Scans, Sample A, Figure 10-2

This sample is similar to the above eddy current scans except that the operation involves ultrasonic shear wave transducer scans instead of eddy current surface scans. The trend of

the mean has a more gradual rise compared with eddy current scan results. A continued rise is exhibited at the maximum.

Semiautomatic Ultrasonic Shear Wave Scans, Sample A, Figure 10-3

The semiautomatic shear wave inspection was performed with a transducer positioning device. The results show a marked improvement over hand-held transducer scans. Except for the existence of four outlier points, the trend of the mean closely approximates a step function to 1.0 probability in the radial flaw length range from 0.10" to 0.30".

Eddy Current Surface Scans, Sample B, Figure 10-4

Performance of this task was identical to the eddy current scans on Sample A except it was a bench-top activity. The trend of the mean for this sample rises more dramatically from higher probability values in the smaller flaw length region, as contrasted to eddy current results on Sample A. The curve also exhibits an asymptotic character as it reaches the upper end of the flaw length range. This is a feature of the regression fit which is common to all the curves but is not as pronounced where initial slopes are low.

Overhead Eddy Current Surface Scans, Sample B, Figure 10-5

The trends for this case are not decidedly different from those depicted in Figure 10-4. Since there was no apparent influence due to overhead scans contrasted to bench-type eddy current NDI, this task was discontinued after the sixth base visit.

Radiographic NDI, Sample B, Figure 10-6

This plot shows a great amount of scatter because the radiographic method is more sensitive to crack opening than to crack length. The task involved precise aiming of x-rays to obtain good quality of exposures, using the equipment trailer as a simulated fuselage structure. The results show a gradual rise in mean detection probabilities with increasing crack length similar to that shown in Figure 10-2. The 95% lower confidence bound, however, is somewhat less because of the scatter.

Penetrant NDI, Sample C, Figure 10-7

The task of penetrant NDI on this sample required participants to view indications both overhead and below, within the interior of Structure Sample A. The results are similar in curve shape to those depicted in Figure 10-4.

Ultrasonic Shear Wave Scans, Sample C, Figure 10-8

Ultrasonic scans in this task were performed both overhead and below, within Sample A. The plot exhibits little trend information, and wide scatter. The detection probabilities are comparatively high for small cracks but there is no real improvement with increasing flaw lengths.

Eddy Current Bolt-Hole Scans, Sample E, Figure 10-9

This task was performed by incrementing an eddy current probe through bolt holes. The results show a curve shaped like the one in Figure 10-4. The flaw length in this case is axial; not radial as presented in the previous examples. The mean probability point estimates are generally low and observed flaw lengths are confined to range below 0.25". The remainder of the curves are extrapolations.

Automatic Eddy Current Bolt-Hole Scans, Sample E, Figure 10-10

This inspection used automatic equipment with strip chart recordings, as compared with the above manual scans. Trend information is practically nonexistent with only a 0.5 probability increment, for example, over the measured crack length range of 0.05" to 0.25". The capability is, however, markedly improved over that shown in Figure 10-9.

Eddy Current Bolt-Hole Scans, Sample F, Figure 10-11

The performance of manual bolt-hole scans in this task involved probing multilayer configurations. This added element of complexity influenced flaw detection in the 0.15" to 0.25" axial crack length range if comparisons are made with Figure 10-9.

Automatic Eddy Current Bolt-Hole Scans, Sample F, Figure 10-12

This task was performed as the one described for Figure 10-10. The automatic equipment with the recording capability provided the instrument readouts. As in the case with Sample E, a marked improvement over manual operation can be observed.

Ultrasonic Shear Wave Scans, Sample F, Figure 10-13

Ultrasonic NDI on this sample was performed from both outside and inside the structure. The results are plotted with reference to radial crack lengths; in contrast to the above eddy current bolt-hole examples. The low probability values across the entire flaw length range precluded the determination of the lower 95% confidence bound. The curve lacks any pronounced slope change compared with the previous task results on this sample.

Outstanding Depot, Eddy Current Bolt-Hole Scans, Sample E, Figure 10-14

The superior performance with eddy current bolt-hole NDI at the second depot installation is presented for the forged wing fittings. There are seven flaws in this sample but only five point estimates show because there are identical probability values of 1.0 for three 0.20" flaws. The 95% confidence bound was not computed because there was not a sufficient number of participating technicians to provide a valid confidence.

Outstanding Depot, Eddy Current Bolt-Hole Scans, Sample F, Figure 10-15

This plot, which also presents a superior eddy current bolt-hold NDI performance, shows a trend in mean values which is similar to Figure 10-14. This effort, as above, also had a low level of participation, precluding a 95% confidence bound computation.

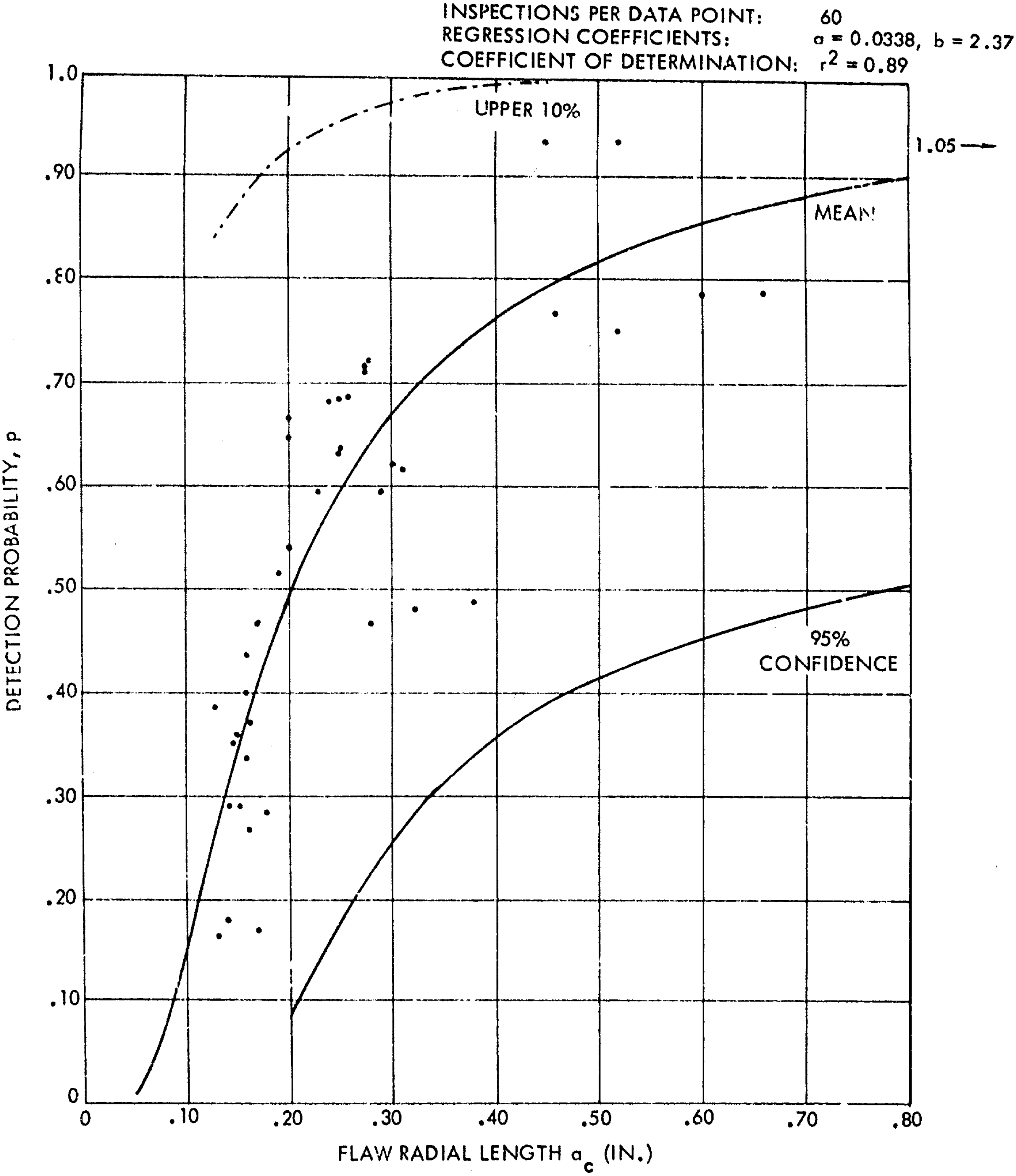


Figure 10-1. Probability of Detection Versus Fatigue Crack Radial Length, Eddy Current Surface Scans Around Countersunk Fasteners, Skin and Stringer Wing Assembly, Sample A.

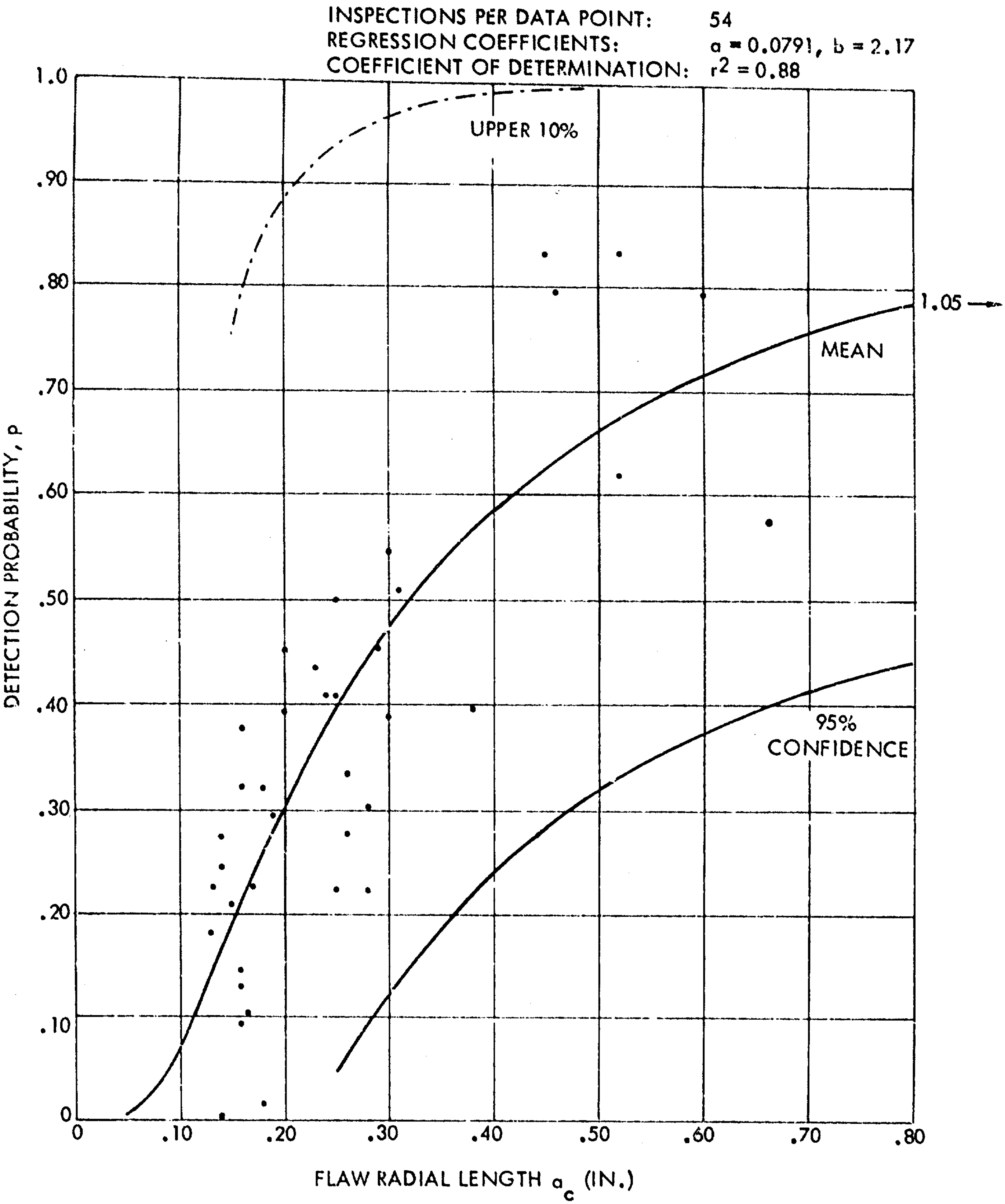


Figure 10-2. Probability of Detection Versus Fatigue Crack Radial Length, Ultrasonic Shear Wave Scans Around Countersunk Fasteners, Skin and Stringer Wing Assembly, Sample A.

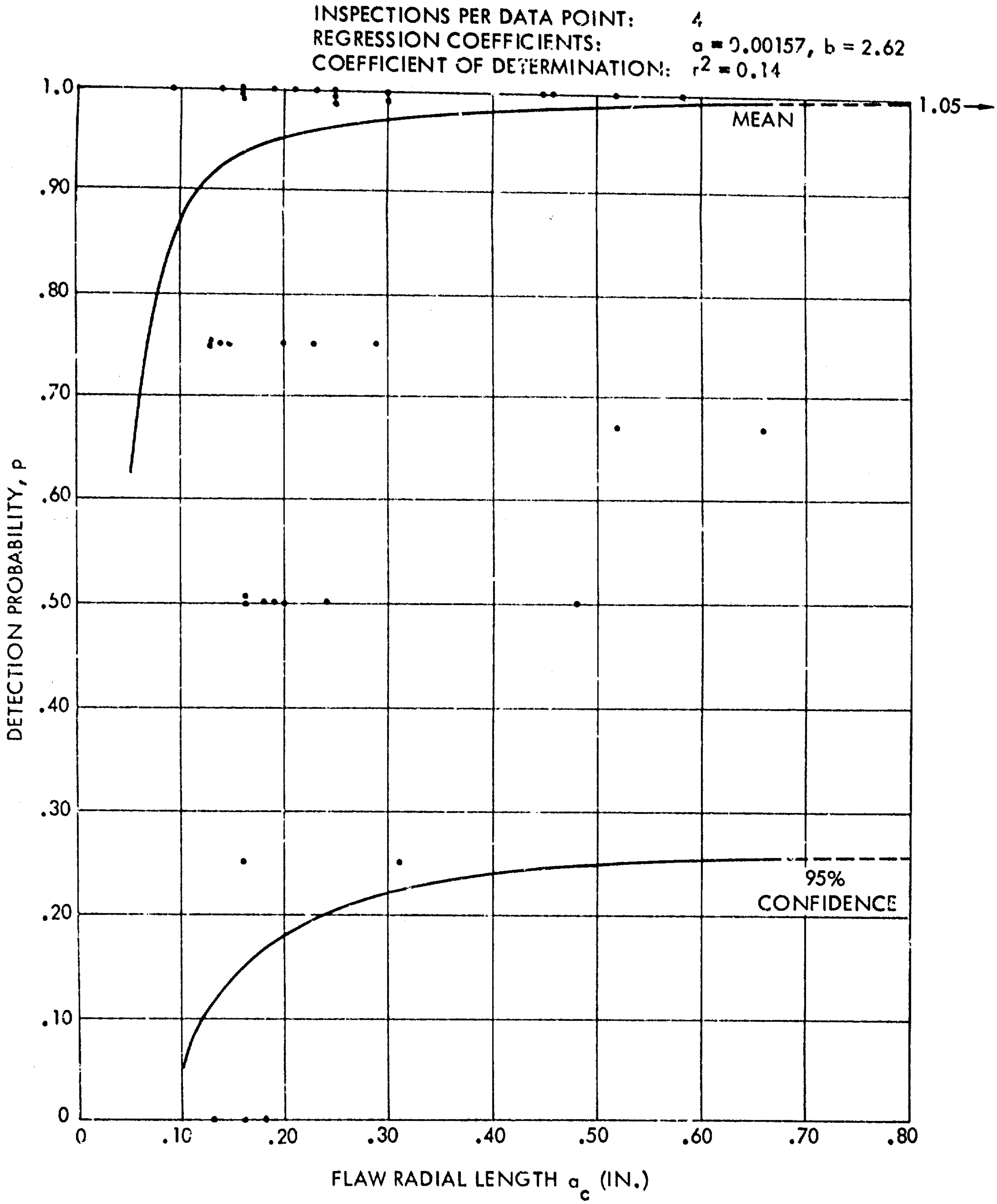


Figure 10-3. Probability of Detection Versus Fatigue Crack Radial Length, Semi-Automatic Ultrasonic Shear Wave Scans Around Countersunk Fasteners, Skin and Stringer Wing Assembly, Sample A.

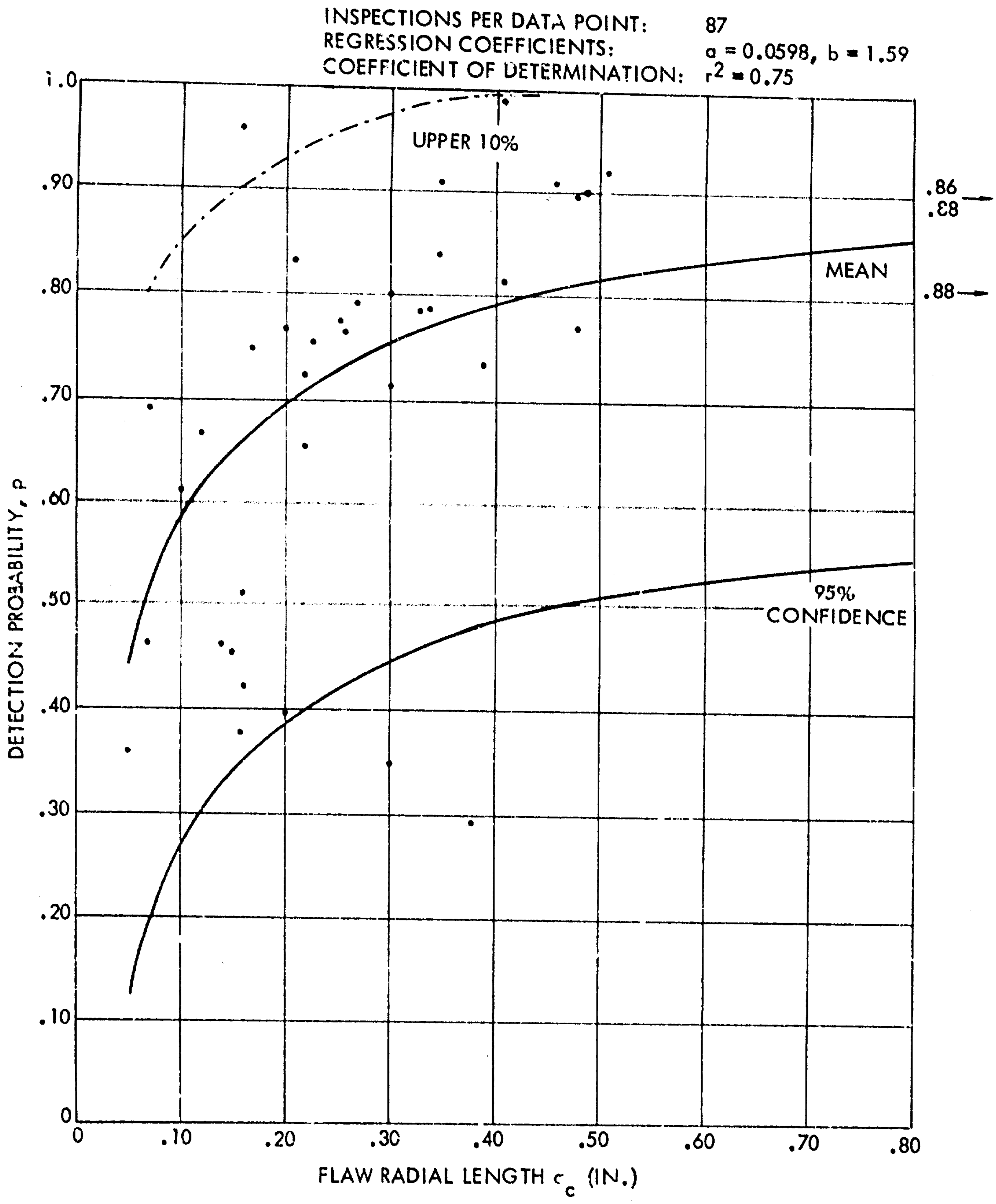


Figure 10-4. Probability of Detection Versus Fatigue Crack Radial Length, Eddy Current Surface Scans Around Countersunk Fasteners, Skin and Stringer Wing Segments, Sample B.

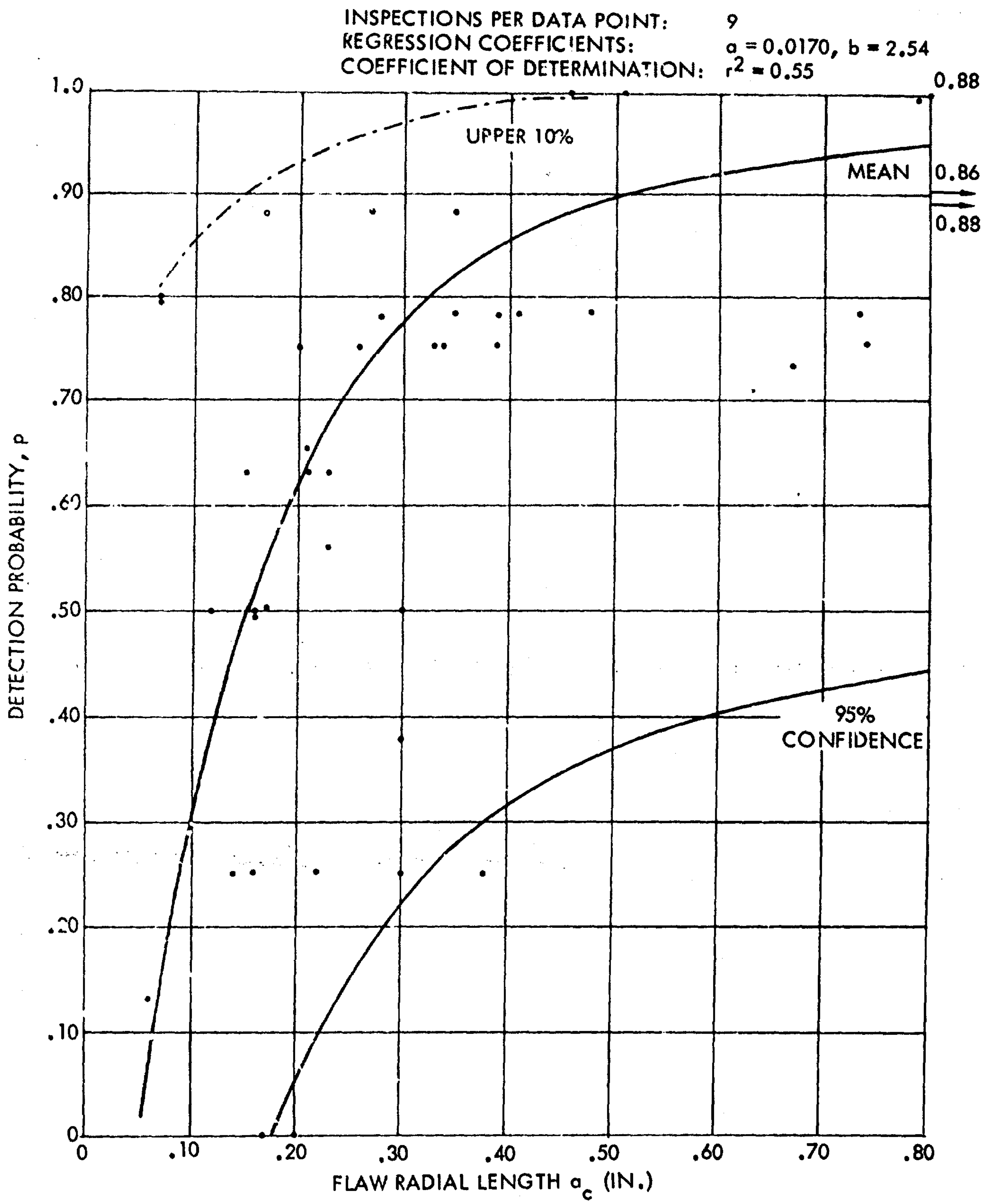


Figure 10-5. Probability of Detection Versus Fatigue Crack Radial Length, Overhead Eddy Current Surface Scans Around Countersunk Fasteners, Skin and Stringer Wing Segments, Sample B.

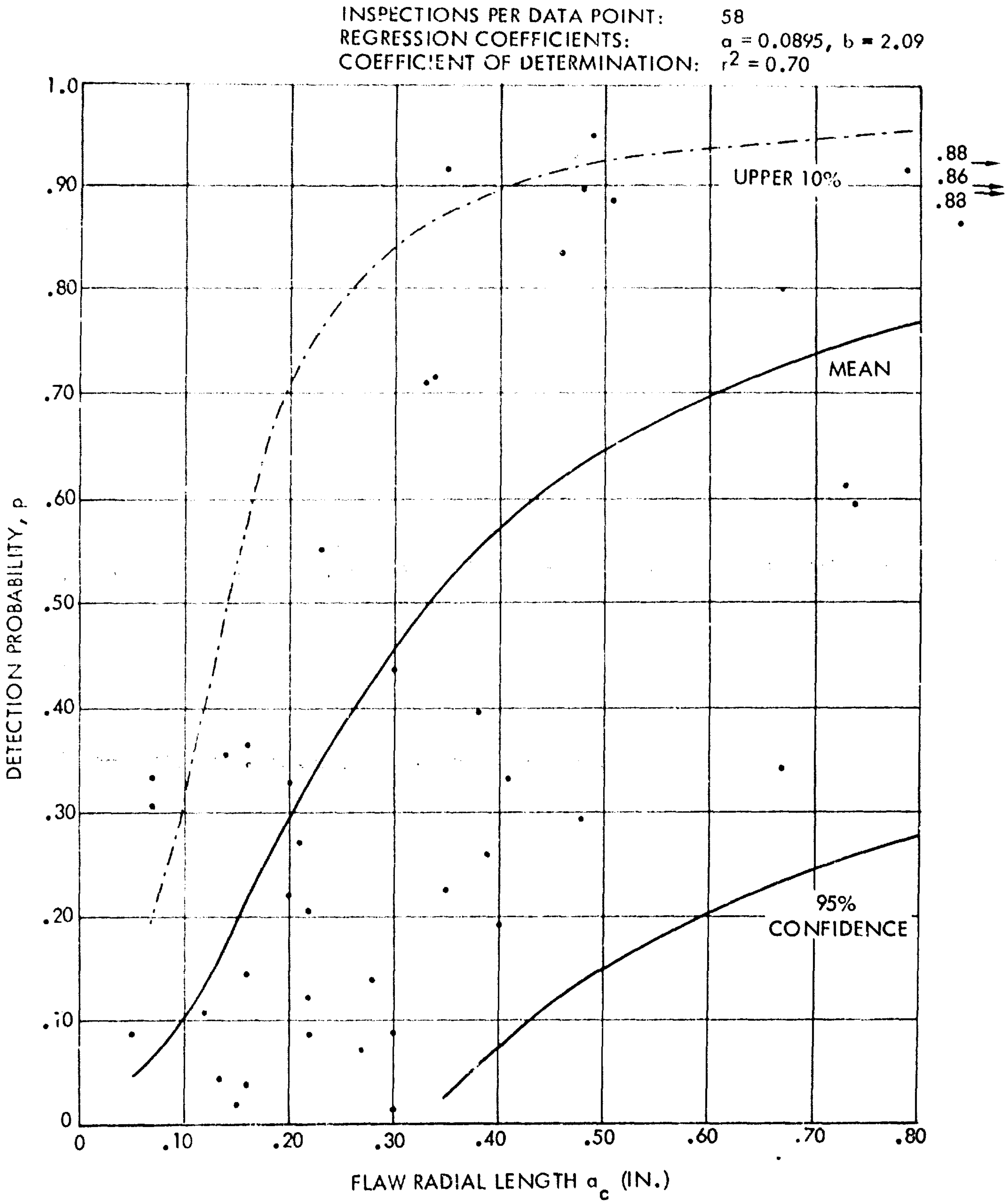


Figure 10-6. Probability of Detection Versus Fatigue Crack Radial Length, Radiographic NDI for Cracks Around Countersunk Fasteners, Skin and Stringer Wing Segments, Sample B.

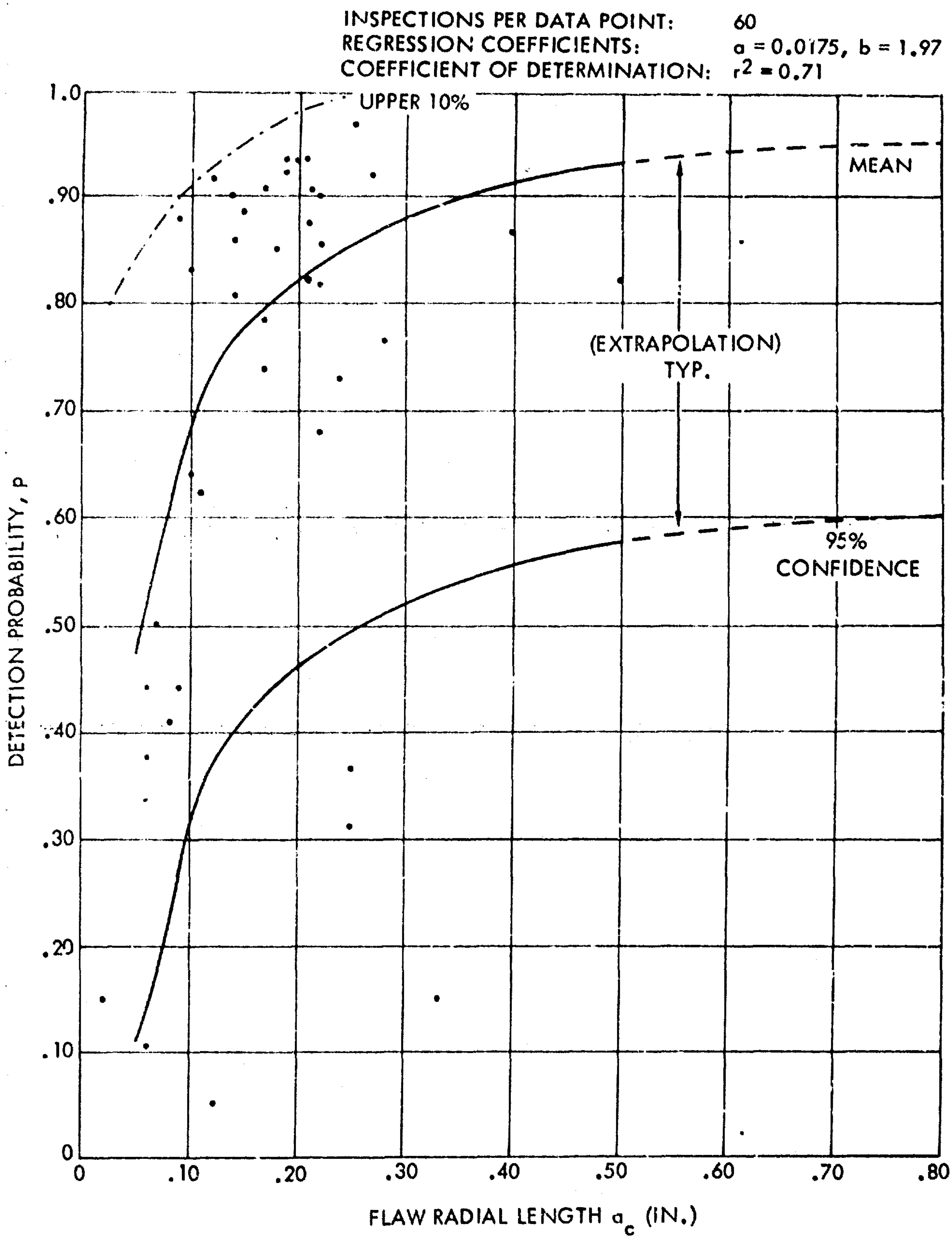


Figure 10-7. Probability of Detection Versus Fatigue Crack Radial Length, Penetrant NDI for Edge Cracks in Simulated Wing Risers, Sample C.

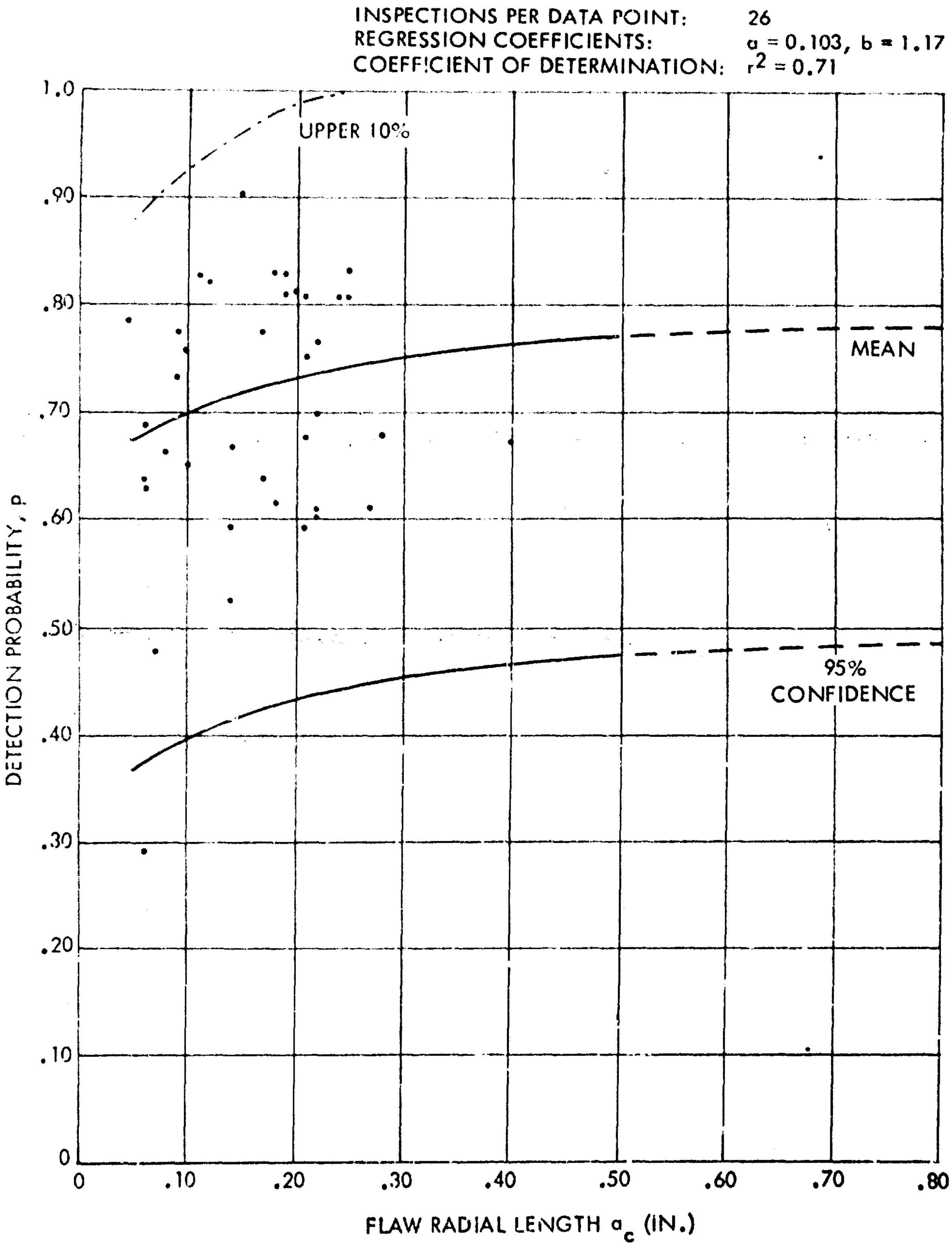


Figure 10-8. Probability of Detection Versus Fatigue Crack Radial Length, Ultrasonic Shear Wave Scans Along Edges of Simulated Wing Risers, Sample C.

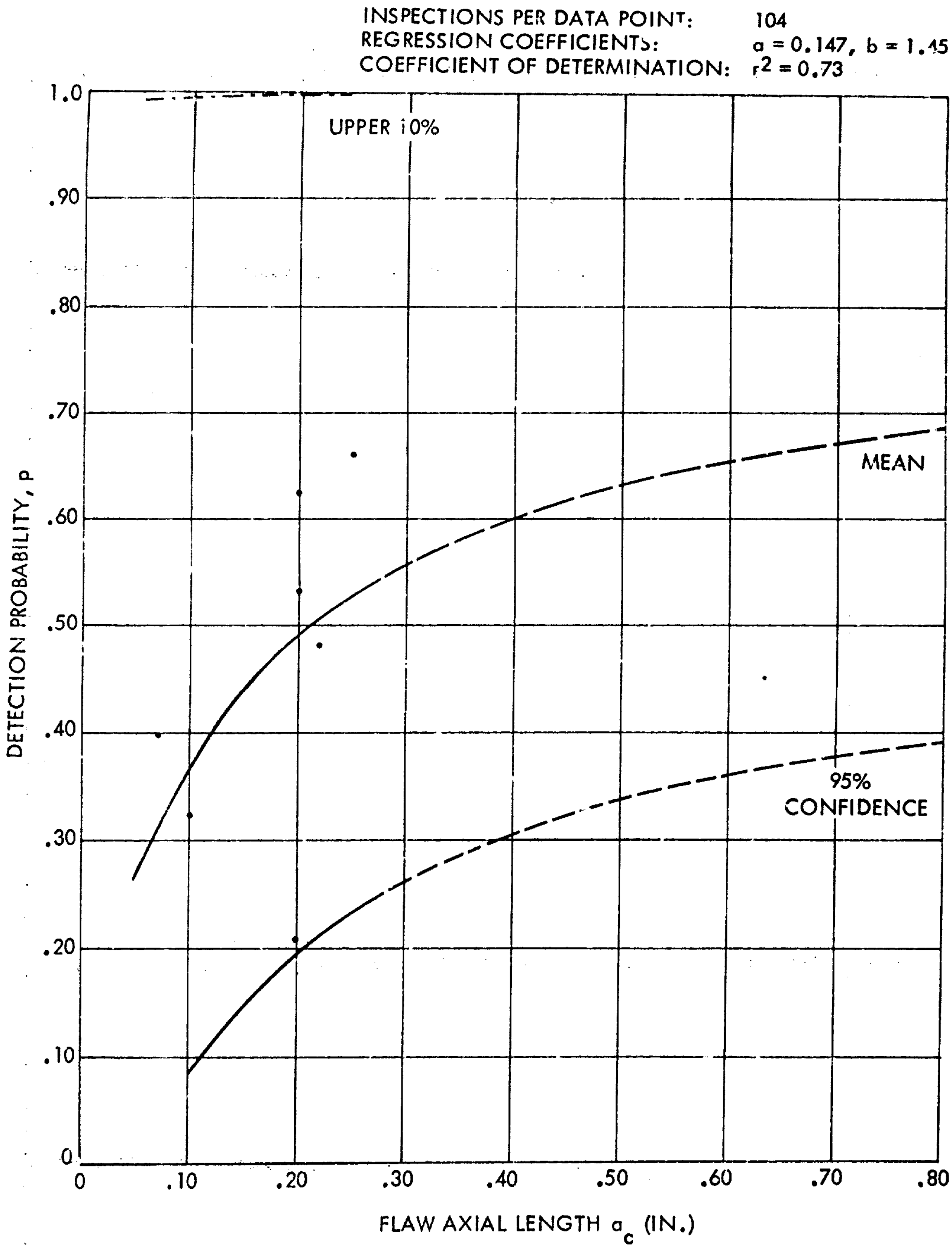


Figure 10-9. Probability of Detection Versus Fatigue Crack Axial Length, Eddy Current Bolt-Hole Rotational Scans, Forged Wing Fittings, Sample E.

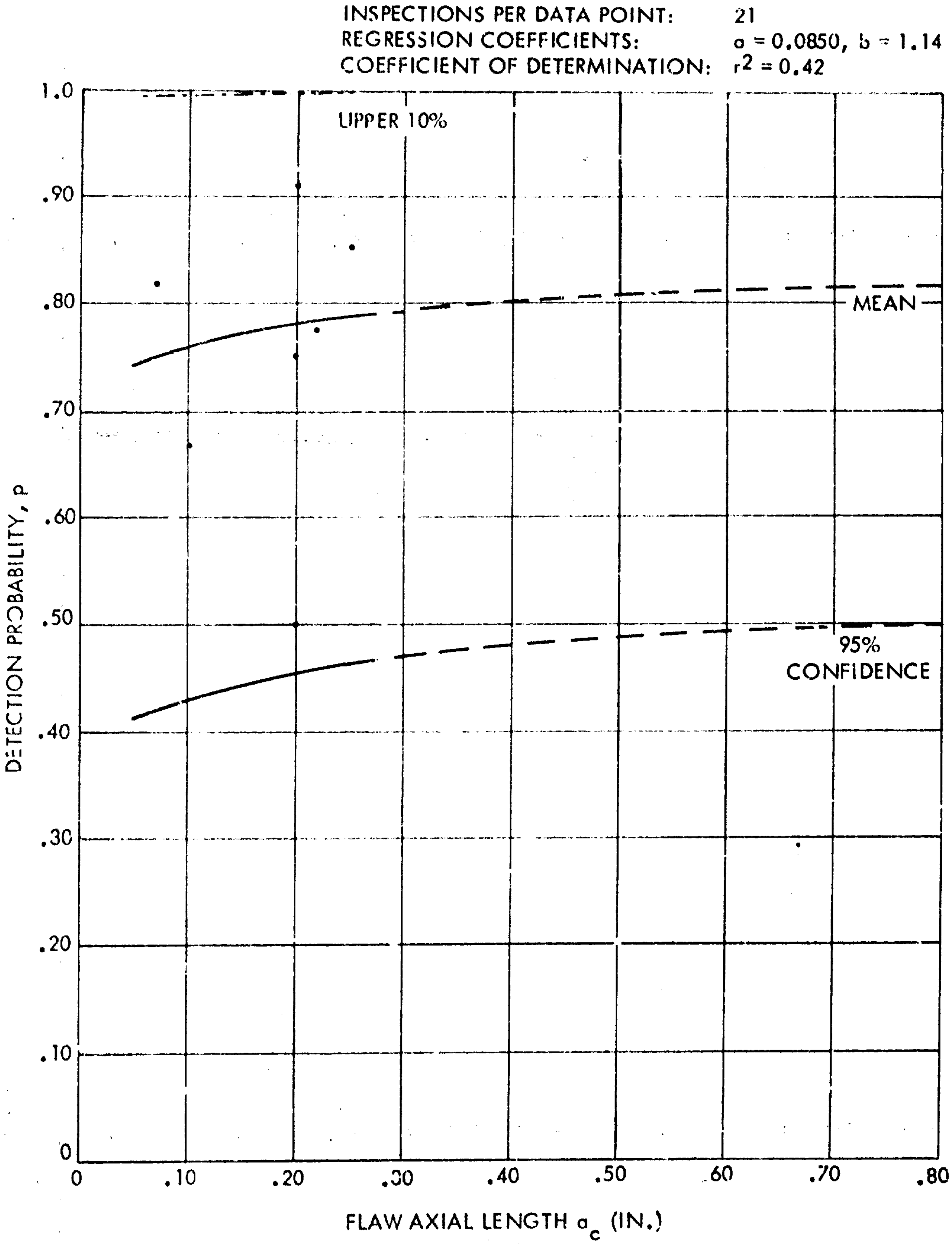


Figure 10-10. Probability of Detection Versus Fatigue Crack Axial Length, Automatic Eddy Current Bolt-Hole Rotational Scans, Forged Wing Fittings, Sample E.

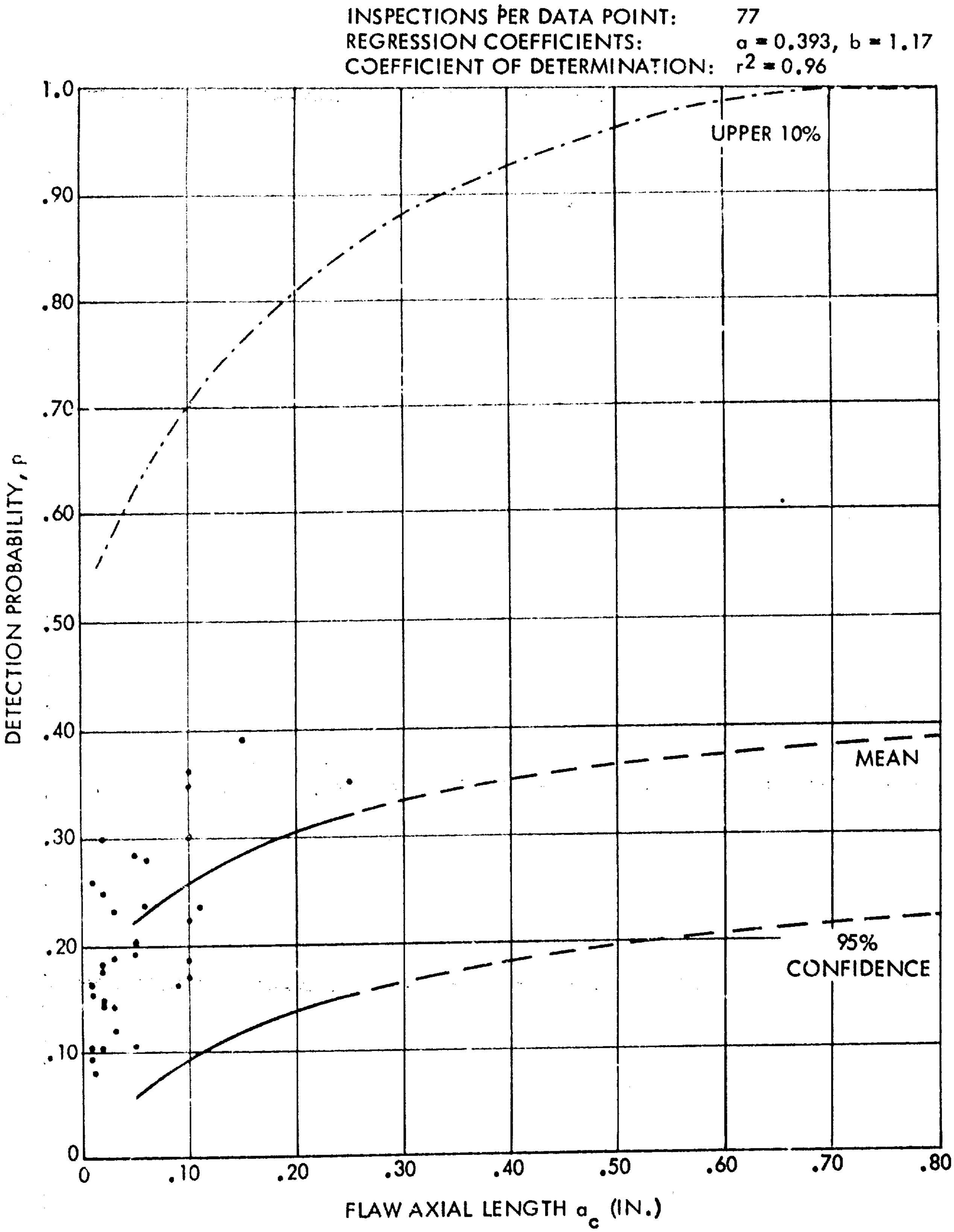


Figure 10-11. Probability of Detection Versus Fatigue Crack Axial Length, Eddy Current Bolt-Hole Rotational Scans, Wing Spar Assembly, Sample F.

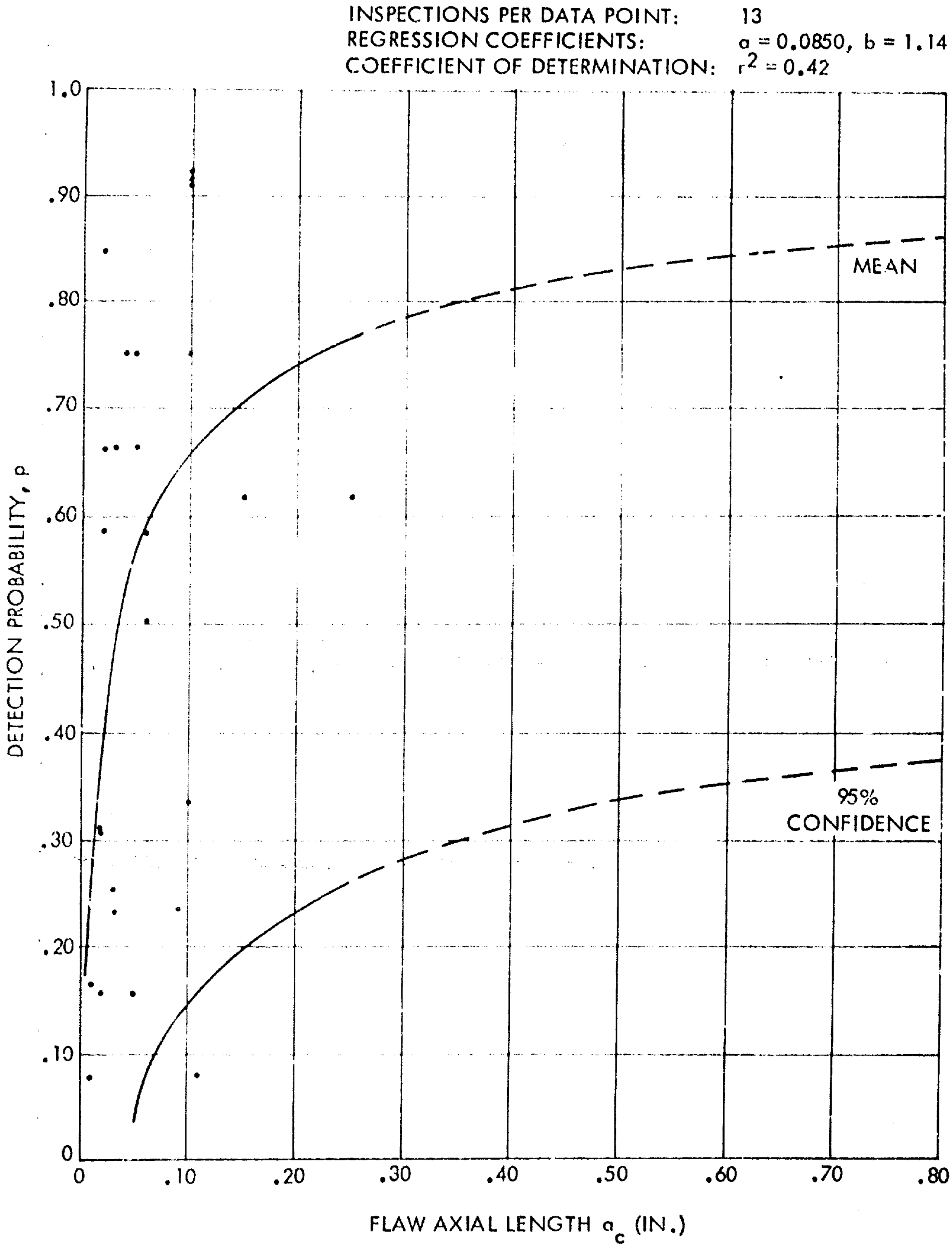


Figure 10-12. Probability of Detection Versus Fatigue Crack Axial Length, Automatic Eddy Current Bolt-Hole Rotational Scans, Wing Spar Assembly. Sample F.

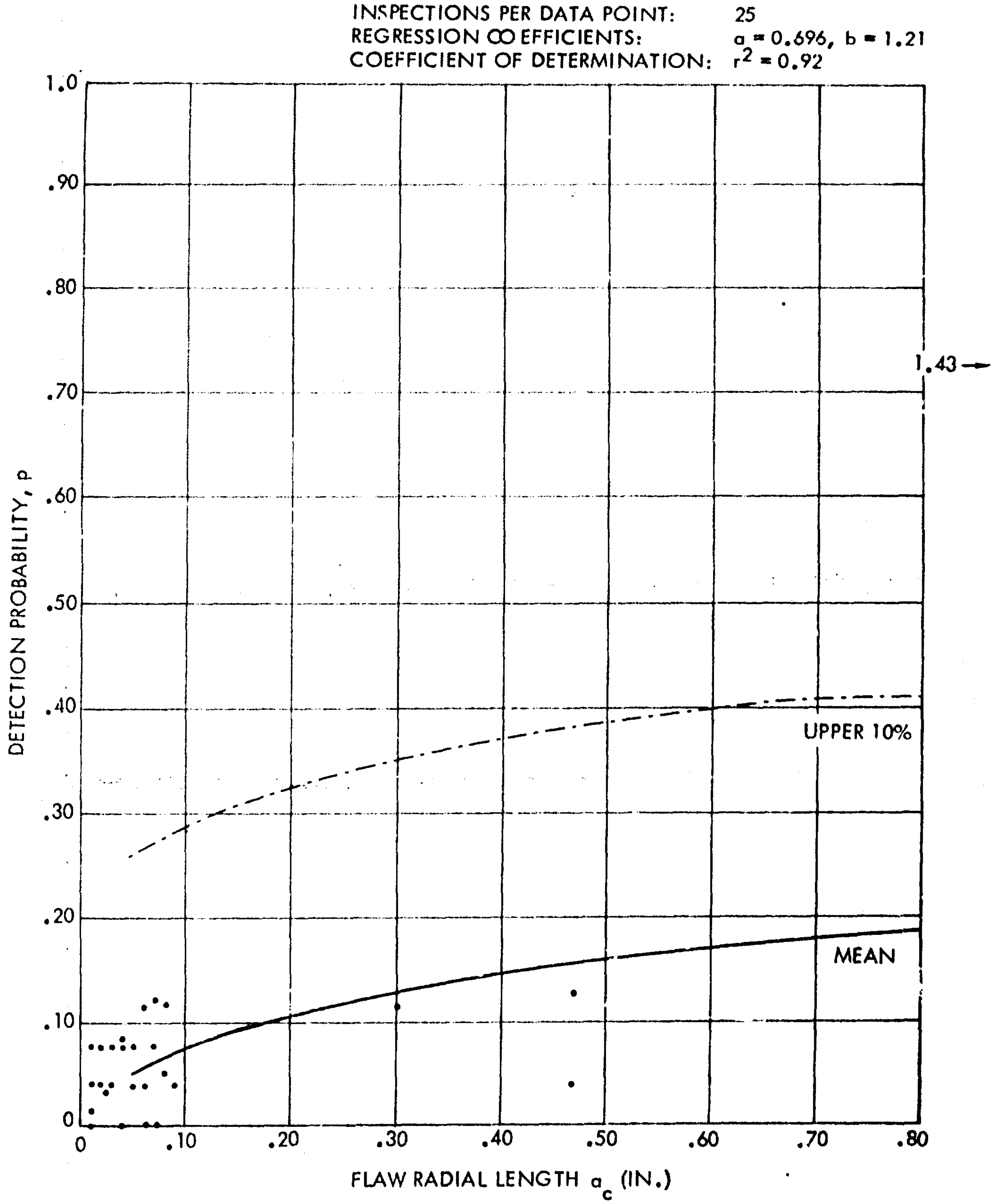


Figure 10-13. Probability of Detection Versus Fatigue Crack Radial Length, Ultrasonic Shear Wave Scans Around Open Fastener Holes, Wing Spar Assembly, Sample F.

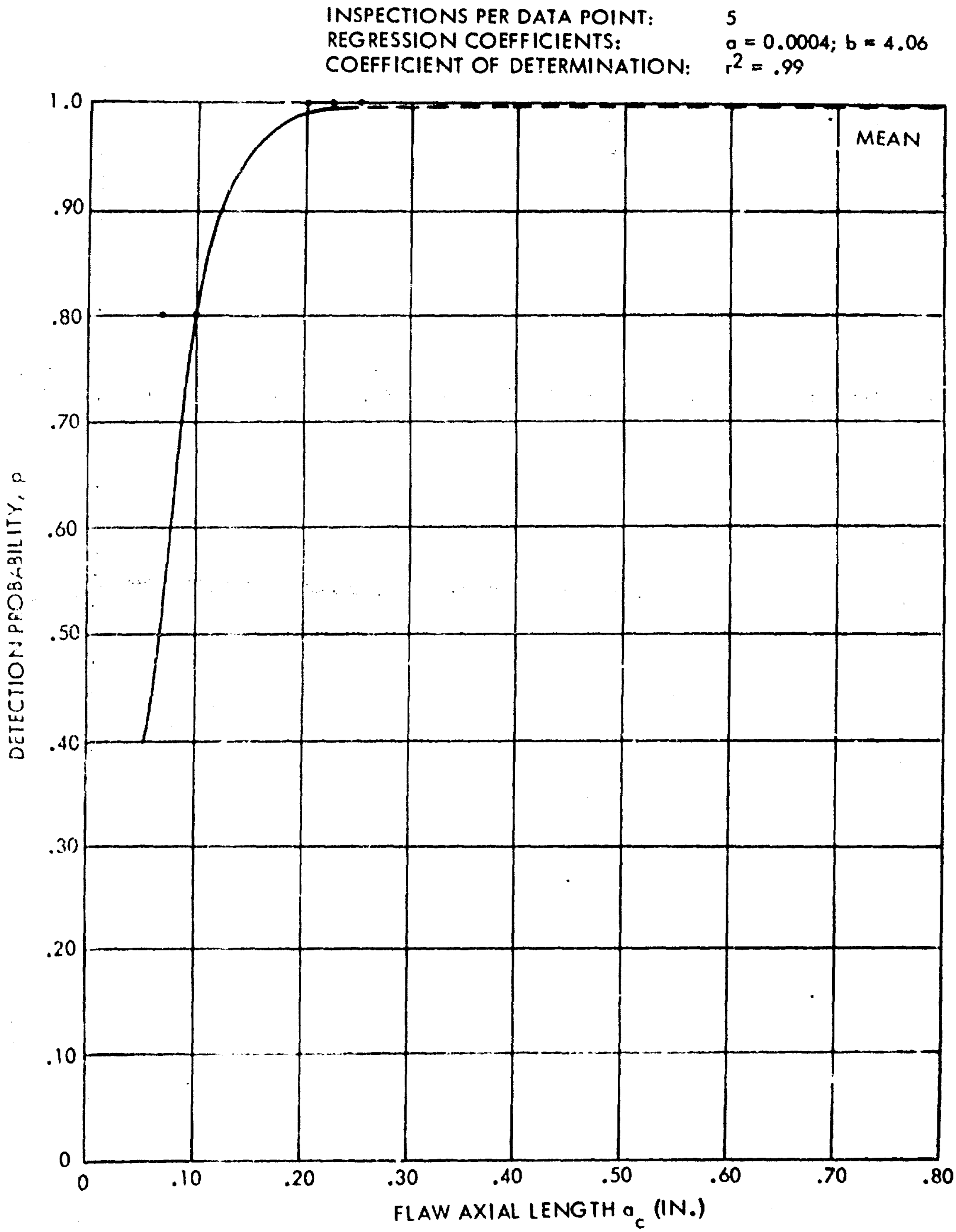


Figure 10-14. Probability of Detection Versus Fatigue Crack Axial Length, Eddy Current Bolt-Hole Rotational Scans, Forged Wing Fittings, Sample E - Outstanding Depot Performance

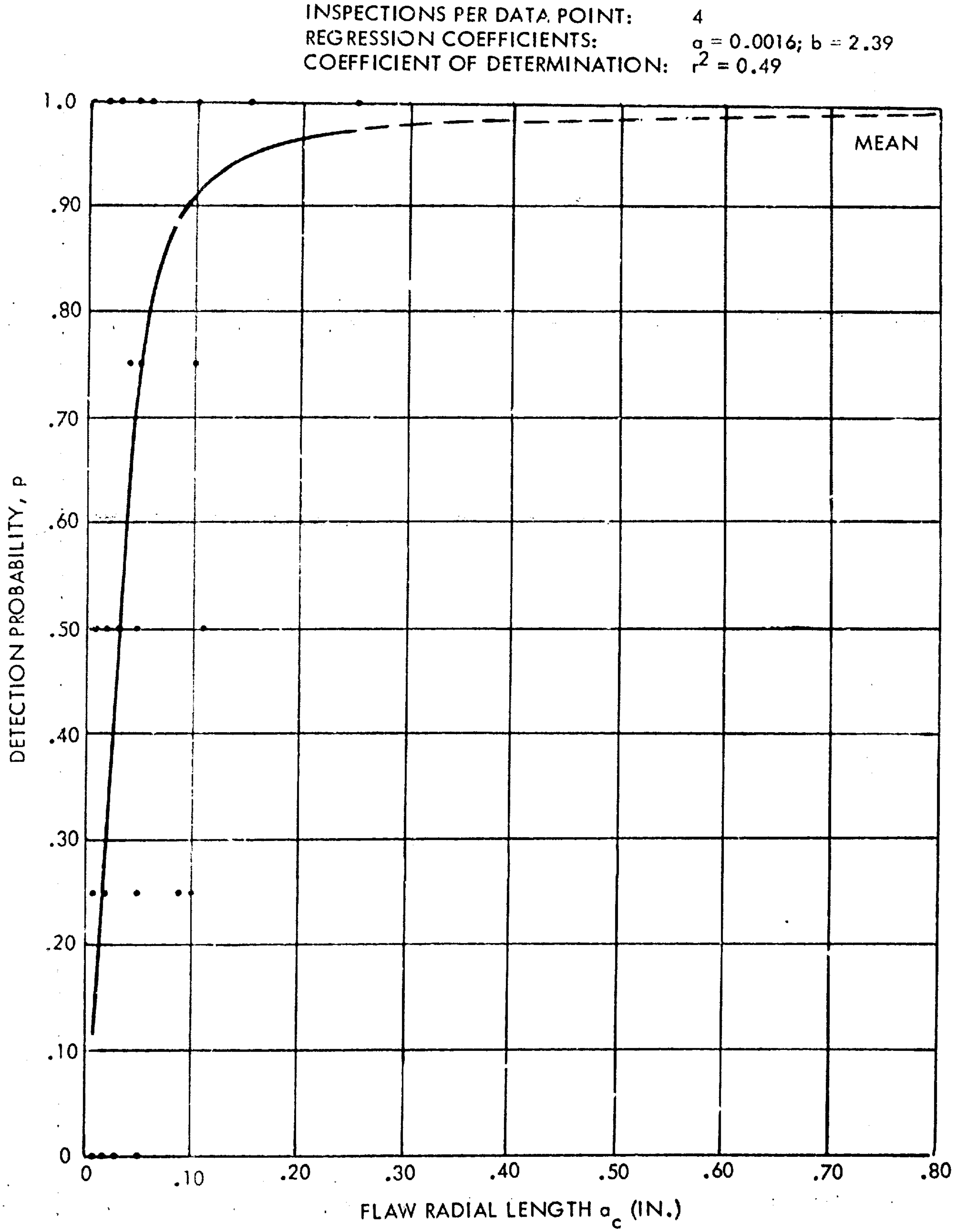


Figure 10-15. Probability of Detection Versus Fatigue Crack Axial Length, Eddy Current Bolt-Hole Rotational Scans, Wing Spar Assembly, Sample F - Outstanding Depot Performance

SECTION XI. DETAILED RELIABILITY FINDINGS

The detailed findings in this program have concentrated on analysis of human factors effects inherent to flaw detection probabilities. Observations of raw data trends which were attributed to individual differences within relatively constant environmental conditions, showed potential for uncovering significant human factors sources of variability. A knowlege of these sources of variability and their relative contributions to flaw detection probabilities allows for defining courses of action for improving NDI performance.

The data management system described in Section VIII, Data Storage and Retrieval, has been employed to select and process raw data to provide a number of detection probability curves which exhibit the effects of identified parameters. These parameters are listed under the heading, Graphic Plots, as part of the comprehensive analysis described in Section IX, Analysis Methodology. A total of thirteen basic analyses, excluding the day of week classifications, have been selected from the comprehensive analysis list for computer plots. Each of the basic analyses contained in this Section has been developed for data combinations of structure type and NDI method within the following categories of variables:

1. All participants (also presented as curves in Section X).
2. Upper 50% performers.
3. All depot participants.
4. Skill level 3; new entrants into NDI.
5. Skill level 5; the majority of practicing technicians.
6. Skill level 7; advanced technicians.
7. Those not graduates of high school.
8. Those under twenty-five years of age.
9. Those over forty years of age.
10. Participants with three years or less experience.
11. Participants with over ten years experience.
12. Participants with up to two hundred NDI training hours.
13. Participants with over five hundred NDI training hours.

In some cases, the qualifications placed on raw data selection for generating a plot have resulted in an insufficient quantity for the curve fitting routine. For example, the raw data available to plot eddy current surface scan detection probabilities on structure sample A, for level 3 personnel was insufficient for the plotting routine and does not appear in the series of detailed findings. Each of the plots has identical axes with the overall detection probabilities (all technicians) plots at the beginning of each series of sample type/NDI method analyses. Curve fitting and confidence bound calculations were performed using the mathematics presented in Section IX.

The computer line printer plots in Figures 11-2 through 11-96 display asterisks (*) for detection probability estimates, periods (.) for calculated data trend approximations, and positive signs (+) for extrapolations. A description of the legend and plotting format is provided in Figure 11-1. The plotting routine operates on fifty increments across the X-axis and seventy increments up the Y-axis. In the event that more than one probability value exists within a 1/50 by 1/70 area, the plotting routine combines them to print a single point estimate. Therefore, the number of flaws listed for each plot may be larger than the number of asterisks (*) printed.

Two additional findings are graphically presented, following the computer plots. These are manually plotted treatments of the effects of environmental temperature on performing radiographic NDI and the effects attributed to differences in the ultrasonic equipment used. Figure 11-97 shows two mean detection probability curves for radiographic NDI; one representing combined results under winter temperature conditions at Dover AFB, Delaware, where exposures were made in unheated hanger space and at Pease AFB, New Hampshire, in an outdoor environment. The other curve represents exposure at room temperature on warm outdoor conditions. The trends exhibited by the means in the upper length range are different but not proven significant in a statistical sense. The 95% confidence bounds for the "extreme" environment are $\pm$ 0.45 and for the "normal" environment are $\pm$ 0.33 (in the flaw length range from 0.70" to 0.80"). The confidence bounds overlap. The curves in Figure 11-98 depict two probability mean trends for ultrasonic inspection performed on Sample A, using two different vendor's ultrasonic equipment. Environmental conditions and the general range of technician performance for each were the same. As in the previous case, the trend of the means is different but not significant. The 95% confidence bounds for each curve in the 0.45" to 0.80" crack length range is $\pm$ 0.16 and they thereby overlap.

LEGEND FOR DATA PLOTS

Sample:	Sample type designations "A" through "F", described in Section III.
Method:	NDI Methods, ET (Eddy Current Surface Scans), UT (Ultrasonic Shear Wave), PT (Penetrant), RT (Radiography), EH (Eddy Current Current Bolt-Hole Scans).
No. of Inspectors:	Total number of individual inspections.
No. of Flaws:	Aggregate total of flaws in the Sample.
Input Record:	Processing code for data accession.
Confidence Level:	Statistically calculated boundary to account for data scatter.
Coefficient of Correlation:	A measure of linear regression fit of point estimates in the transformations $X = 1/a_c$, $Y = (\mathrm{Log}\ 1/p)/a_c$, where 1.000 represents an ideal fit (See Section IX).
Coefficient of Determination:	A measure of the point estimate regression fit to the exponential $y = a(x)^b$, where 1.000 represents an ideal fit (see Section IX).
Standard Error of Estimate:	A measure of deviation of point estimates from the linear regression line where small values indicate low scatter.
X Axis is:	As noted.
Equation:	Y = A*X**B: Line printer format for the equation $y = a(x)^b$, Coefficients A = a and B = b.

Figure 11-1. Legend Description and Plotting Format for Figure 11-2 through 11-96.

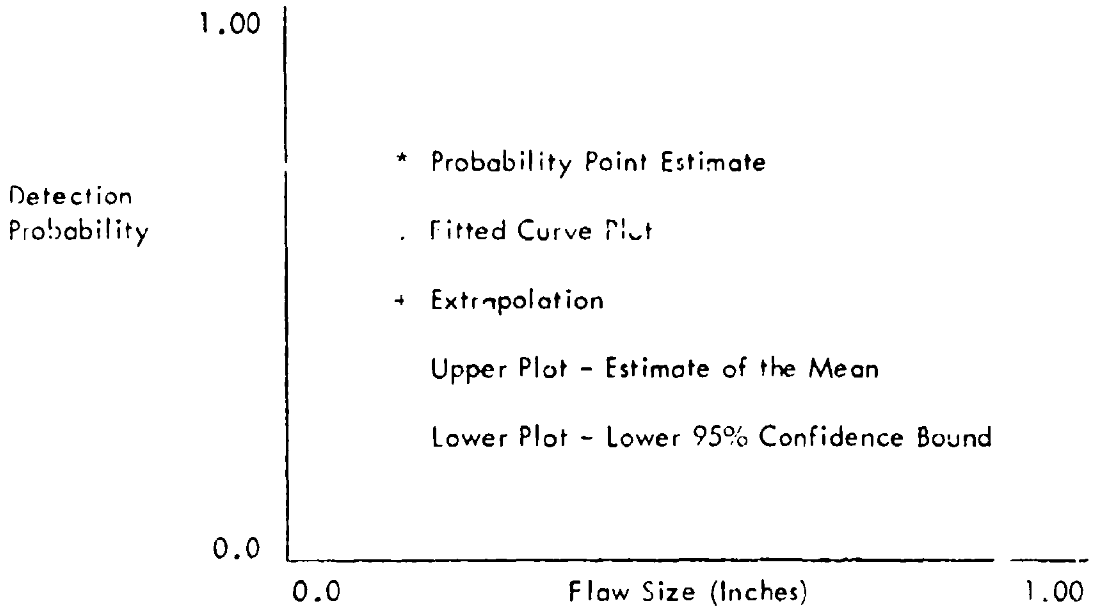


Figure 11-1. (cont'd) Legend Description and Plotting Format for Figure 11-2 through 11-96.

SAMPLE: A

METHOD: ET

NO OF INSPECTORS: 62

NO OF FLAWS: 41

INPUT RECORD: 01 A ET 1 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).

ALL TECH. SAMPLE A (ET)

EQUATION Y=A*X**B A = 0.390528D-01 B = 2.304175

COEFFICIENT OF CORRELATION - 0.869 COEFFICIENT OF DETERMINATION - 0.897

STANDARD ERROR OF ESTIMATE - 0.10

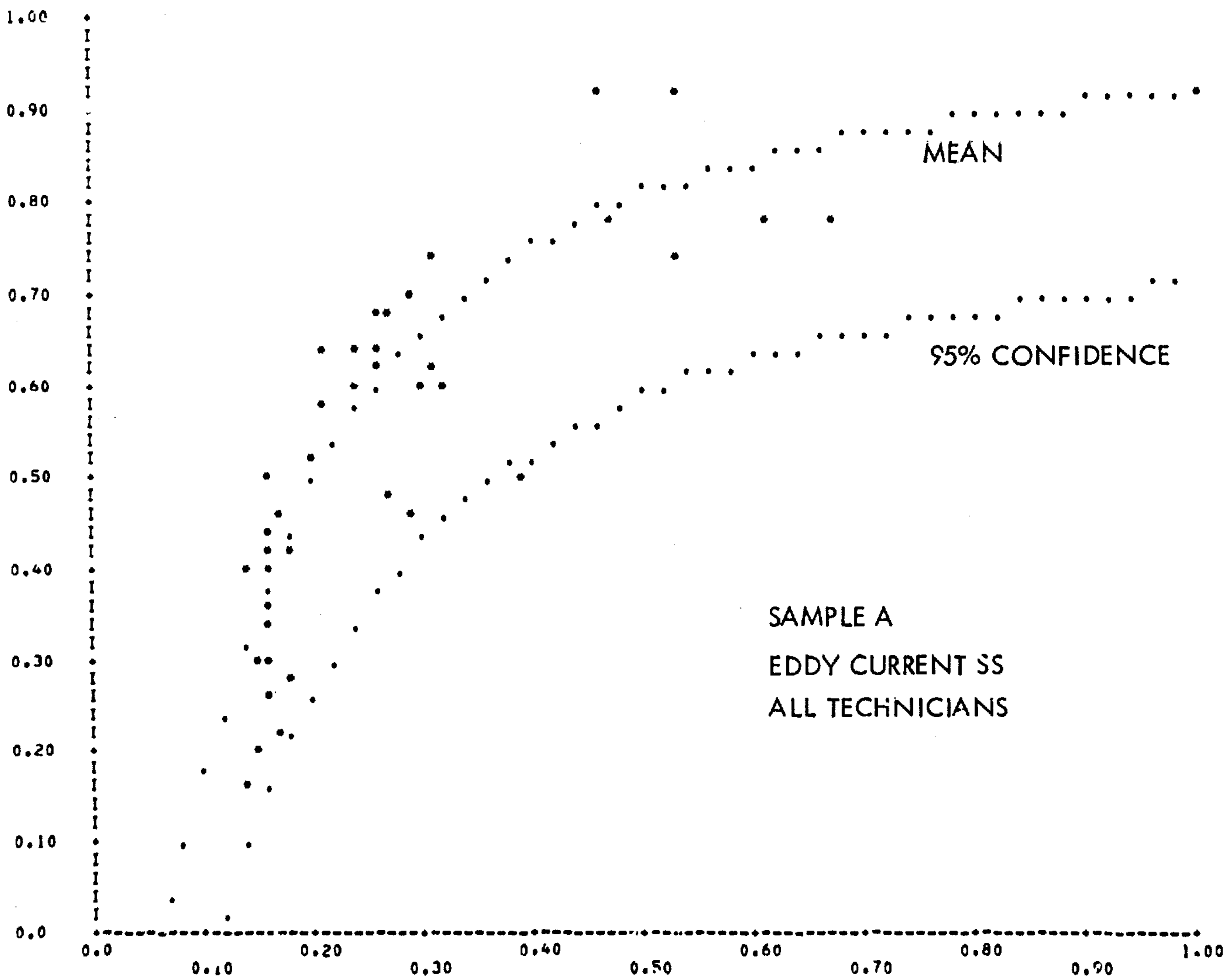


Figure 11-2

SAMPLE: A

METHOD: ET

NO OF INSPECTORS: 34

NO OF FLAWS: 41

INPUT RECORD: 02 A ET 1 52 99 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).

UPPER 50% ALL TECH SAMPLE A (ET)

EQUATION Y=A*X**B A = 0.1335640-01 B = 2.595002

COEFFICIENT OF CORRELATION = 0.774 COEFFICIENT OF DETERMINATION = 0.844

STANDARD ERROR OF ESTIMATE = 0.12

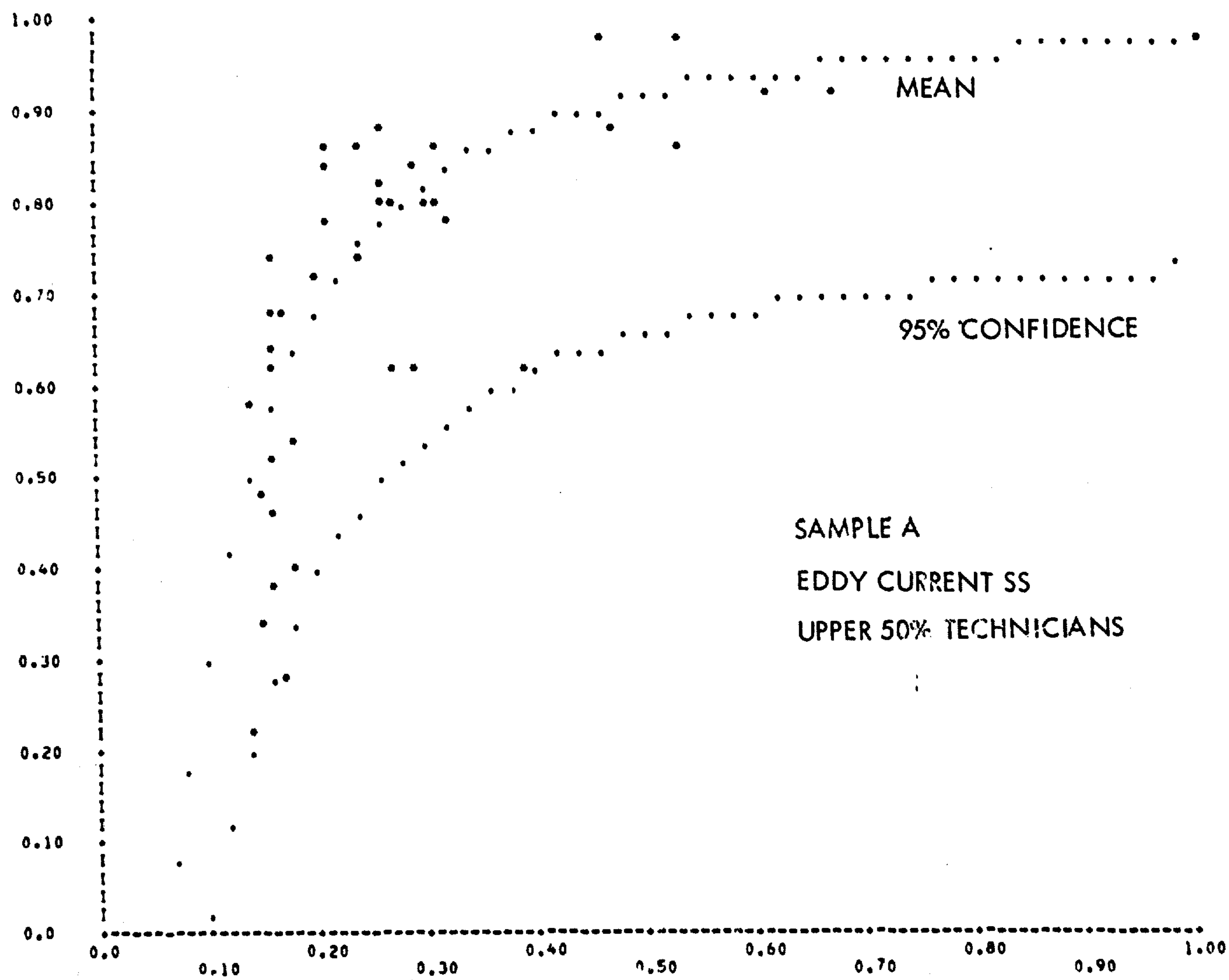


Figure 11-3

SAMPLE: A

METHOD: ET

NO OF INSPECTORS: 31

NO OF FLAWS: 41

INPUT RECORD: 03 A ET 1 0 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).

DEPOT TECH SAMPLE A (ET)

EQUATION Y=A*X**B A = 0.3296330-01 B = 2.354134

COEFFICIENT OF CORRELATION = 0.839

COEFFICIENT OF DETERMINATION = 0.867

STANDARD ERROR OF ESTIMATE = 0.11

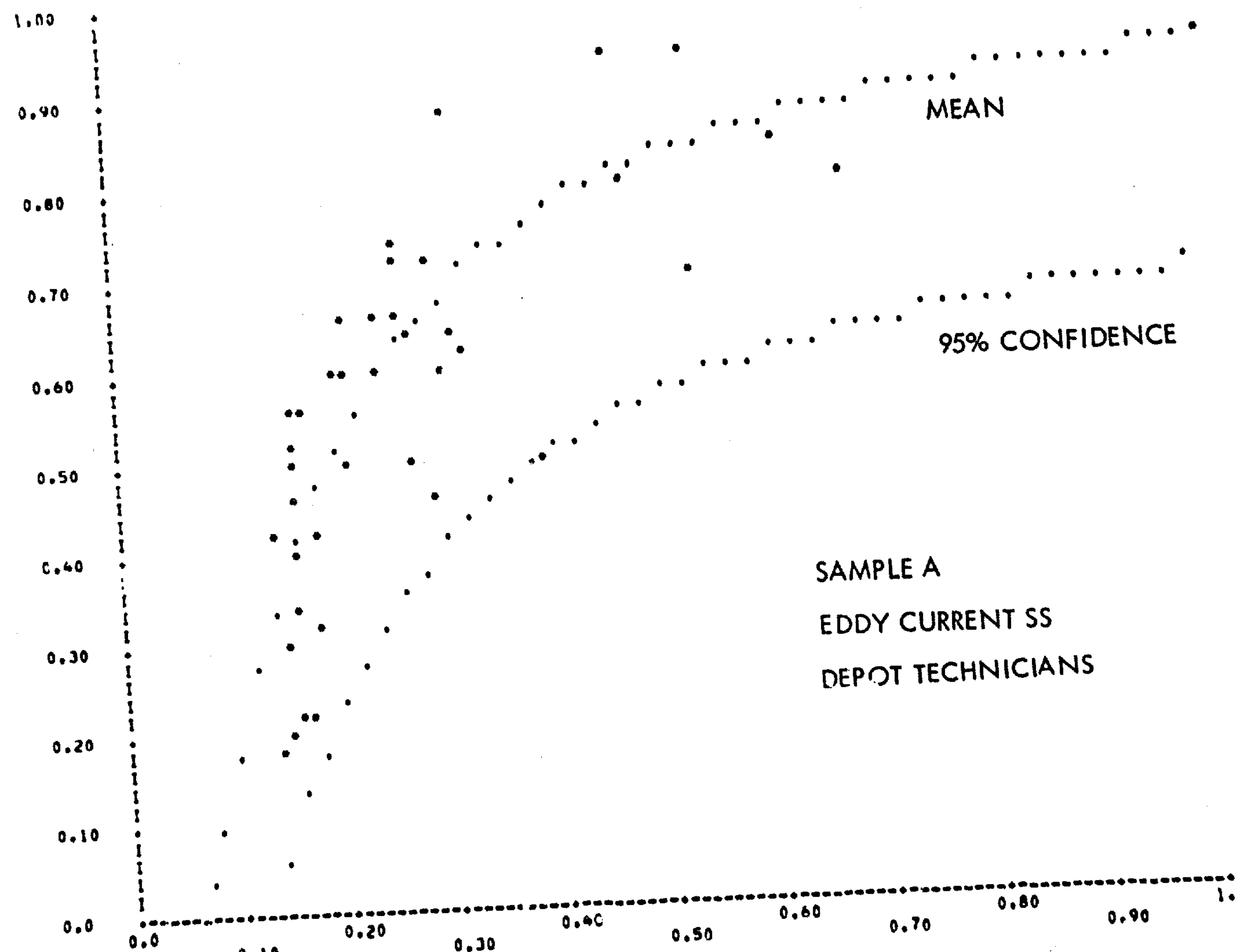


Figure 11-4

SAMPLE: A

METHOD: ET

NO OF INSPECTORS: 51

NO OF FLAWS: 41

INPUT RECORD: 05 A ET 1 5 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).

TECH SKILL LEVEL 5 SAMPLE A (ET)

EQUATION Y=A*X**B A = 0.369832D-01 B = 2.338112

COEFFICIENT OF CORRELATION = 0.844 COEFFICIENT OF DETERMINATION = 0.886

STANDARD ERROR OF ESTIMATE = 0.11

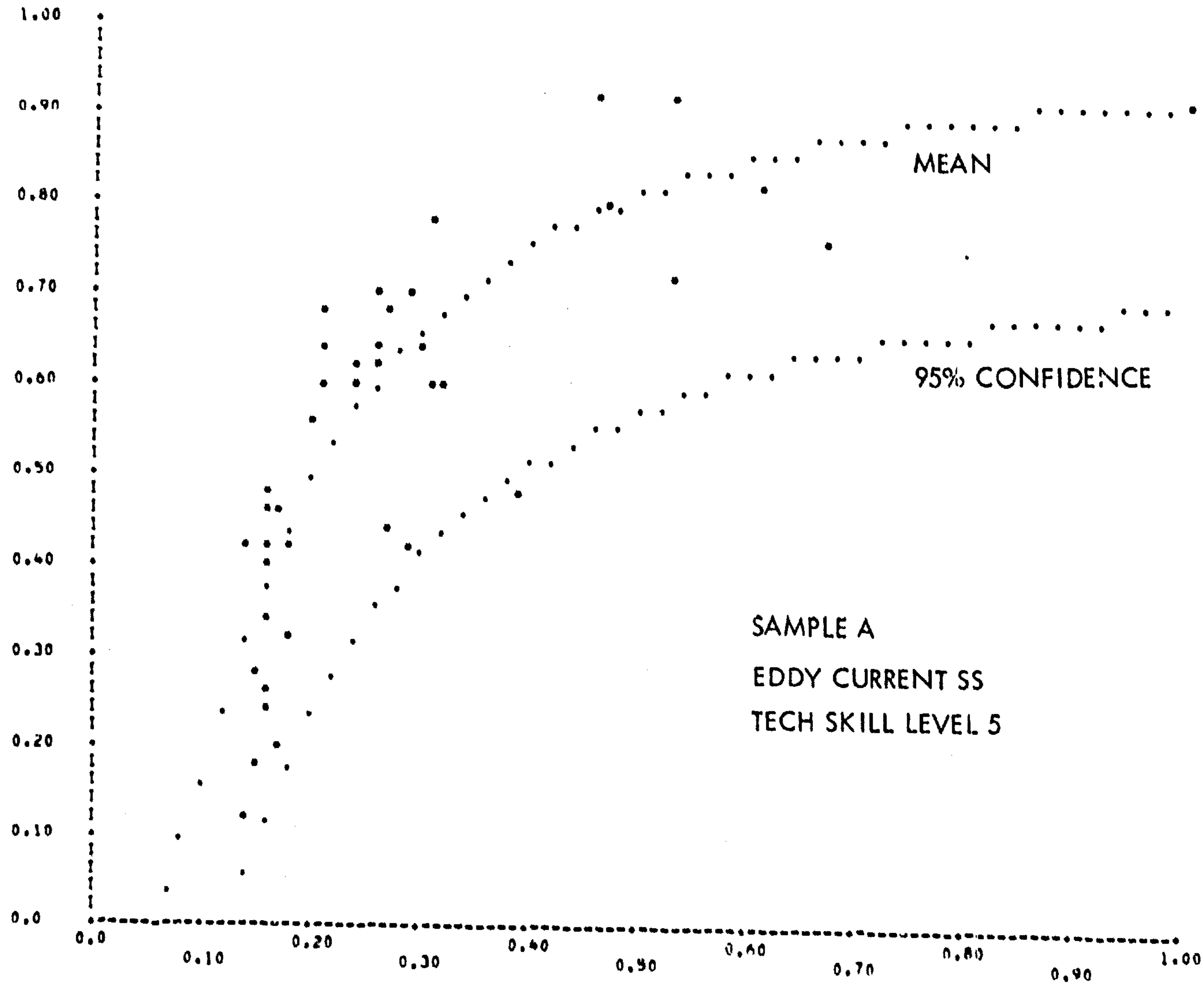


Figure 11-5

SAMPLE: A

METHOD: ET

NO OF INSPECTORS: 9

NO OF FLAWS: 41

INPUT RECORD: 05 A ET 1 7 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).

TECH SKILL LEVEL 7 SAMPLE A (ET)

EQUATION Y=A*X**B A = 0.476715D-01 B = 2.268160

COEFFICIENT OF CORRELATION - 0.700 COEFFICIENT OF DETERMINATION - 0.802

STANDARD ERROR OF ESTIMATE - 0.15

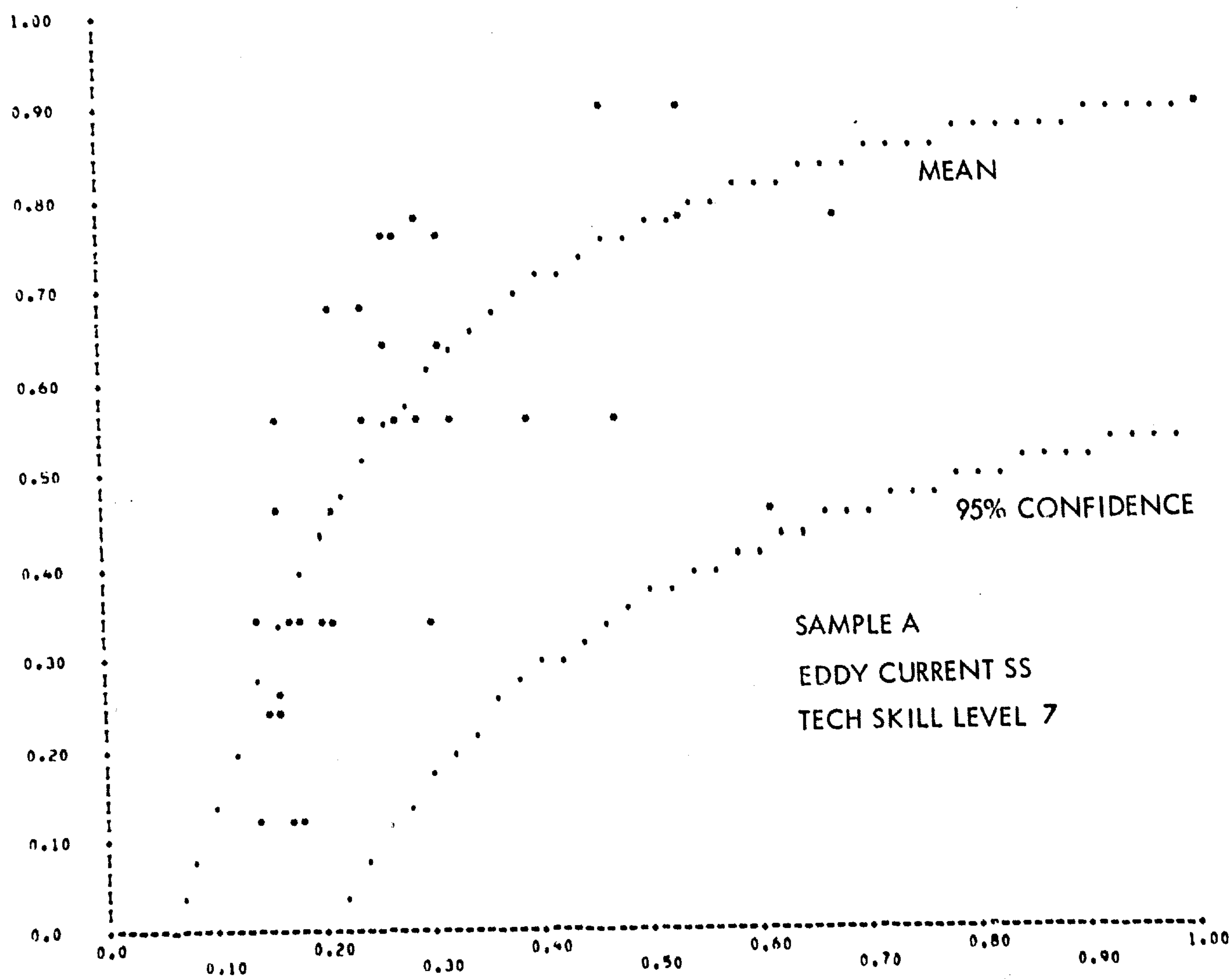


Figure 11-6

SAMPLE: A

METHOD: ET

NO OF INSPECTORS: 17

NO OF FLAWS: 41

INPUT RECORD: 08 A ET 1 150 250 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).

TECH UNDER 25YRS AGE SAMPLE A (ET)

EQUATION Y=A*X**B A = 0.4475670-01 B = 2.342390

COEFFICIENT OF CORRELATION = 0.877 COEFFICIENT OF DETERMINATION = 0.875

STANDARD ERROR OF ESTIMATE = 0.13

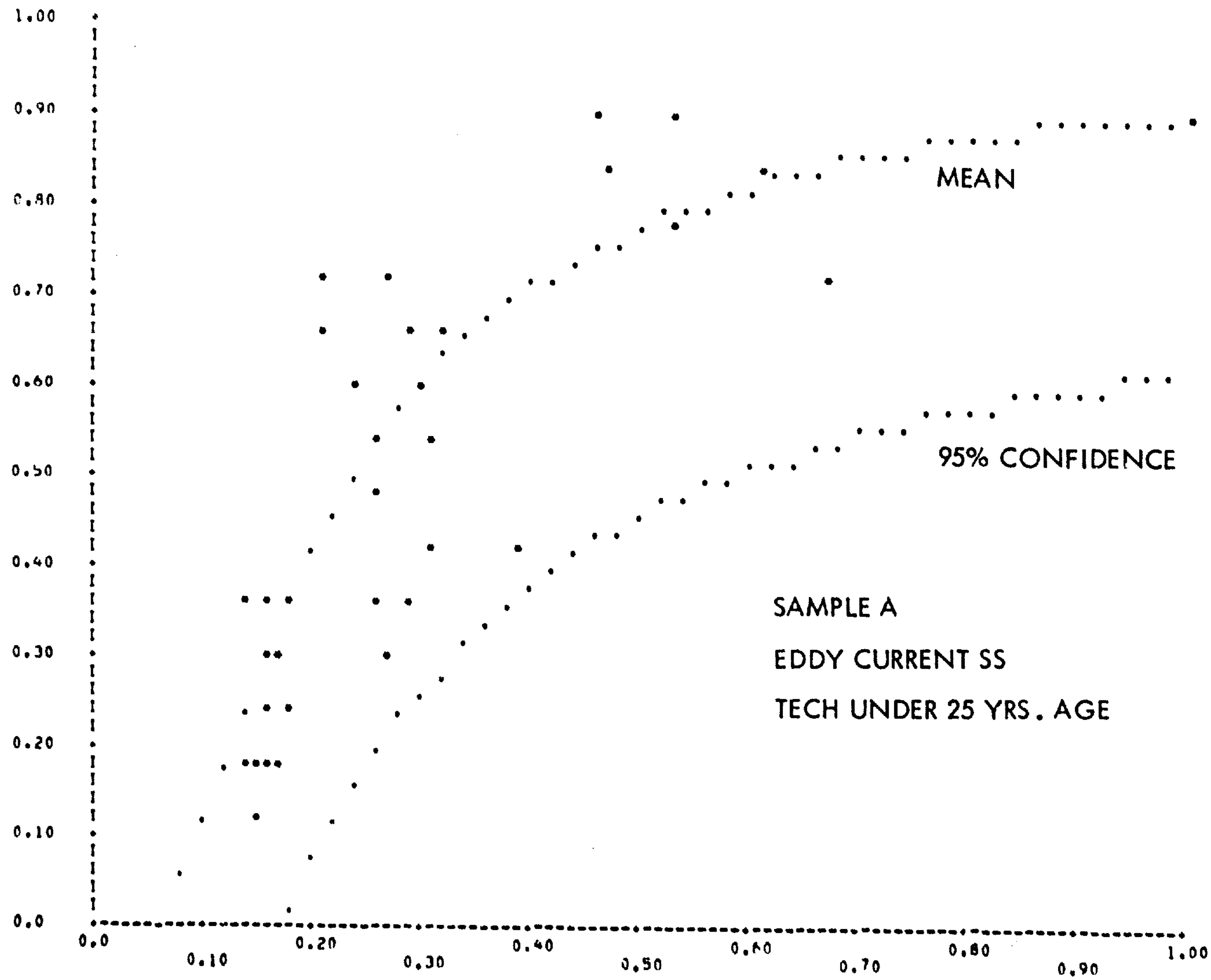


Figure 11-7

SAMPLE: A

METHOD: ET

NO OF INSPECTORS: 16

NO OF FLAWS: 41

INPUT RECORD: 08 A ET 1 400 990 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).

TECH OVER 40YRS AGE SAMPLE A (ET)

EQUATION Y=A*X**B A = 0.2999040-01 B = 2.571095

COEFFICIENT OF CORRELATION - 0.810 COEFFICIENT OF DETERMINATION - 0.843

STANDARD ERROR OF ESTIMATE - 0.14

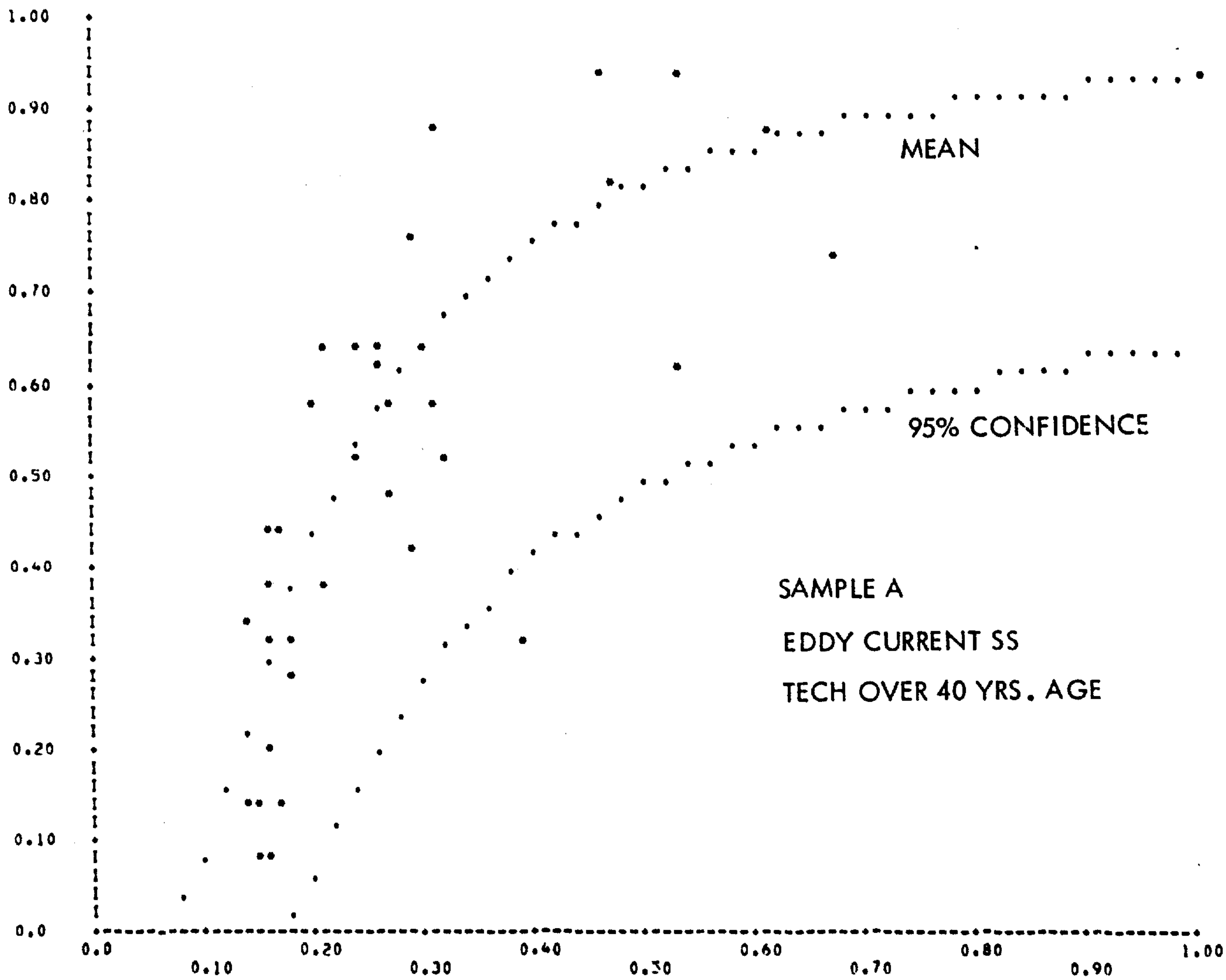


Figure 11-8

SAMPLE: A

METHOD: ET

NO OF INSPECTORS: 41

NO OF FLAWS: 41

INPUT RECORD: 09 A ET 1 011 099 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).

TECH OVER 10 YRS EXPER. SAMPLE A (ET)

EQUATION Y=A*X**B A = 0.3871320-01 B = 2.275178

COEFFICIENT OF CORRELATION = 0.862

COEFFICIENT OF DETERMINATION = 0.883

STANDARD ERROR OF ESTIMATE = 0.10

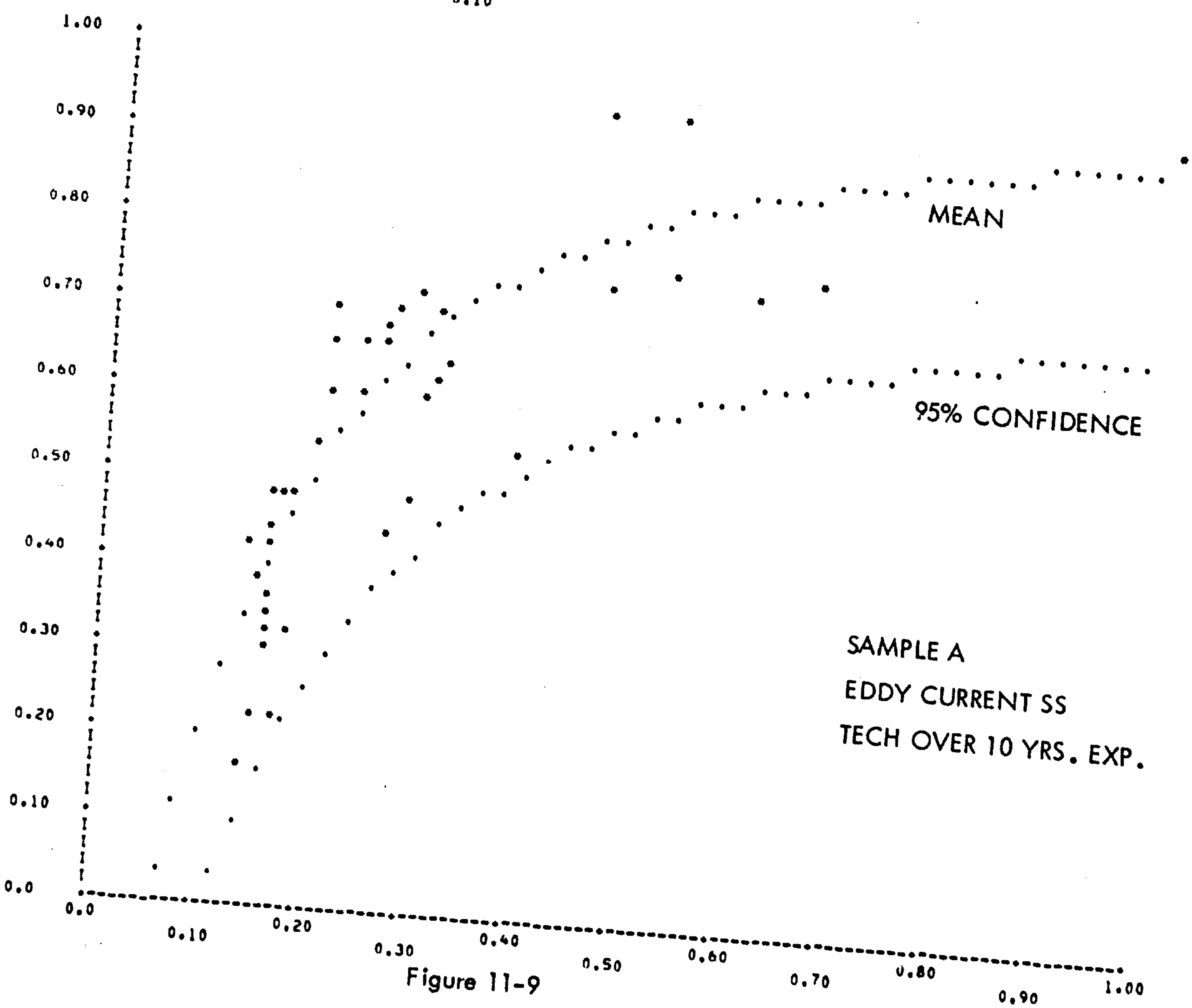


Figure 11-9

SAMPLE: A

METHOD: ET

NO OF INSPECTORS: 30

NO OF FLAWS: 41

INPUT RECORD: 10 A ET 1 000 200 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).

TECH 0-200HRS NDI TRNG SAMPLE A (ET)

EQUATION Y=A*X**B A = 0.352975D-01 B = 2.311401

COEFFICIENT OF CORRELATION - 0.838 COEFFICIENT OF DETERMINATION - 0.864

STANDARD ERROR OF ESTIMATE - 0.12

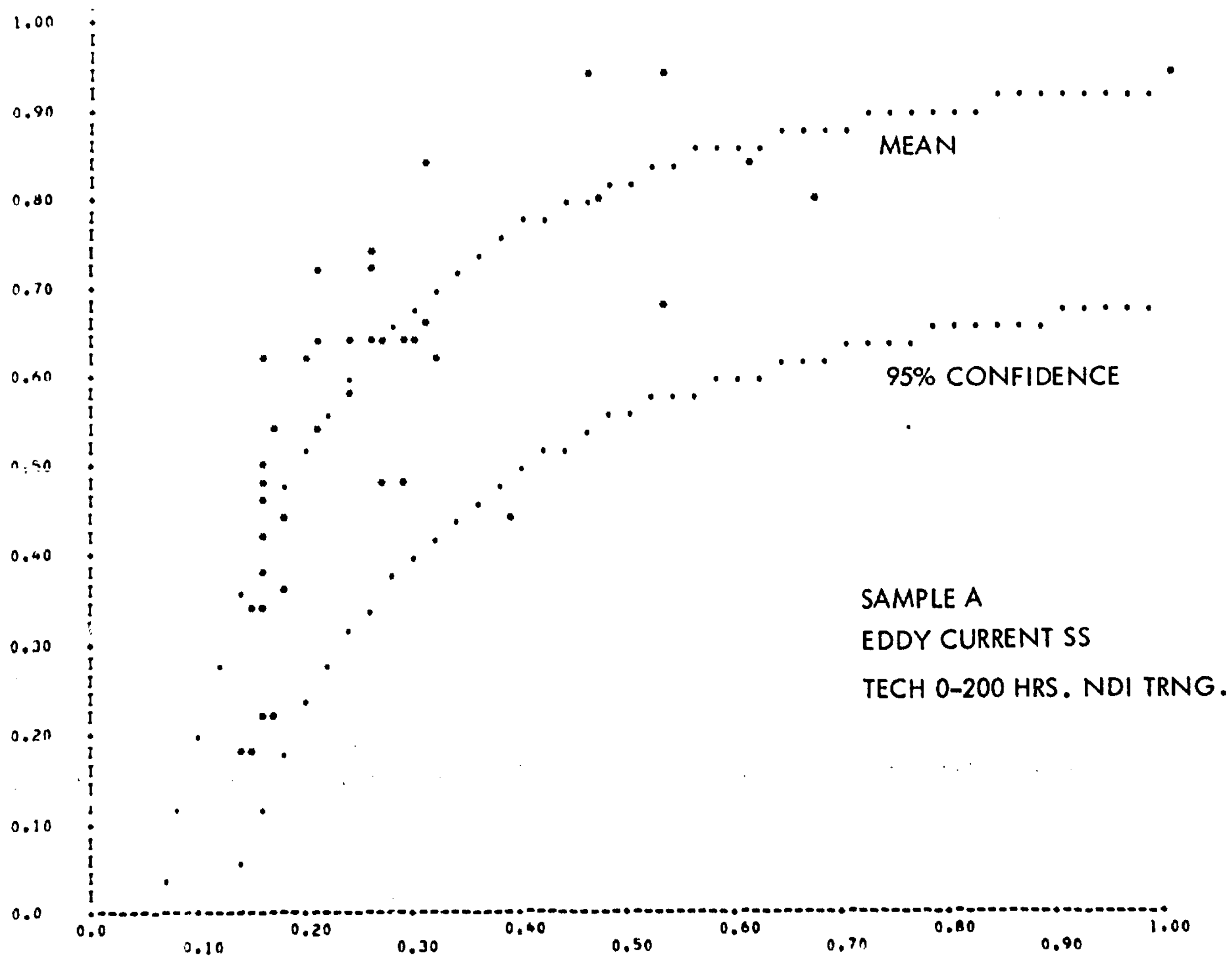


Figure 11-10

SAMPLE: A

METHOD: ET

NO OF INSPECTORS: 10

NO OF FLAWS: 41

INPUT RECORD: 10 A ET 1 500 999 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).

TECH 500+ HRS NDI TRNG SAMPLE A (ET)

EQUATION Y=A*X**B A = 0.5389610-01 B = 2.121464

COEFFICIENT OF CORRELATION = 0.797 COEFFICIENT OF DETERMINATION = 0.777

STANDARD ERROR OF ESTIMATE = 0.15

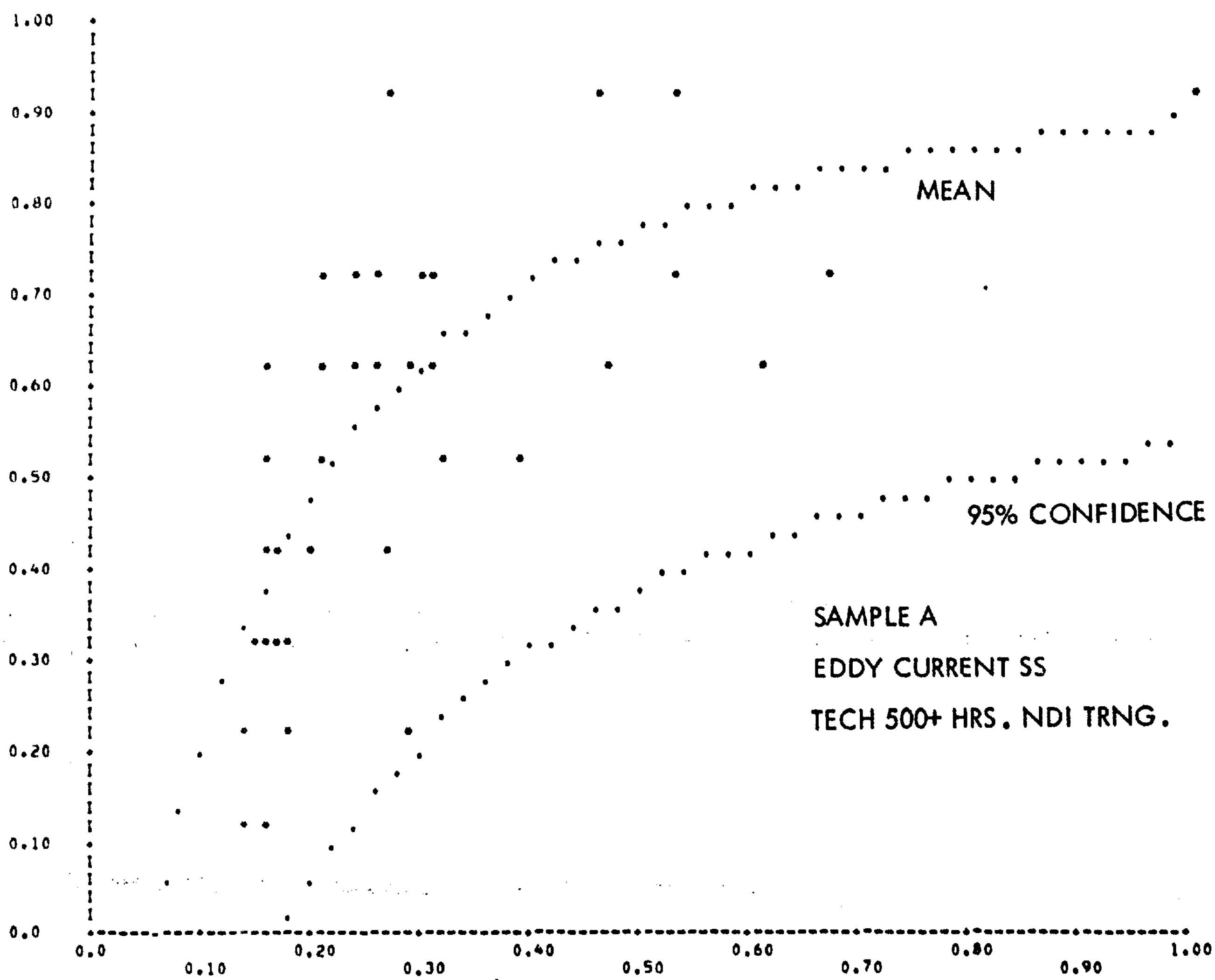


Figure 11-11

SAMPLE: A

METHOD: UT

NO OF INSPECTORS: 54

NO OF FLAWS: 41

INPUT RECORD: 01 A UT 1 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).

ALL TECH. SAMPLE A (UT)

EQUATION Y=A*X**B A = 0.6077880-01 B = 2.248284

COEFFICIENT OF CORRELATION = 0.807 COEFFICIENT OF DETERMINATION = 0.884

STANDARD ERROR OF ESTIMATE = 0.11

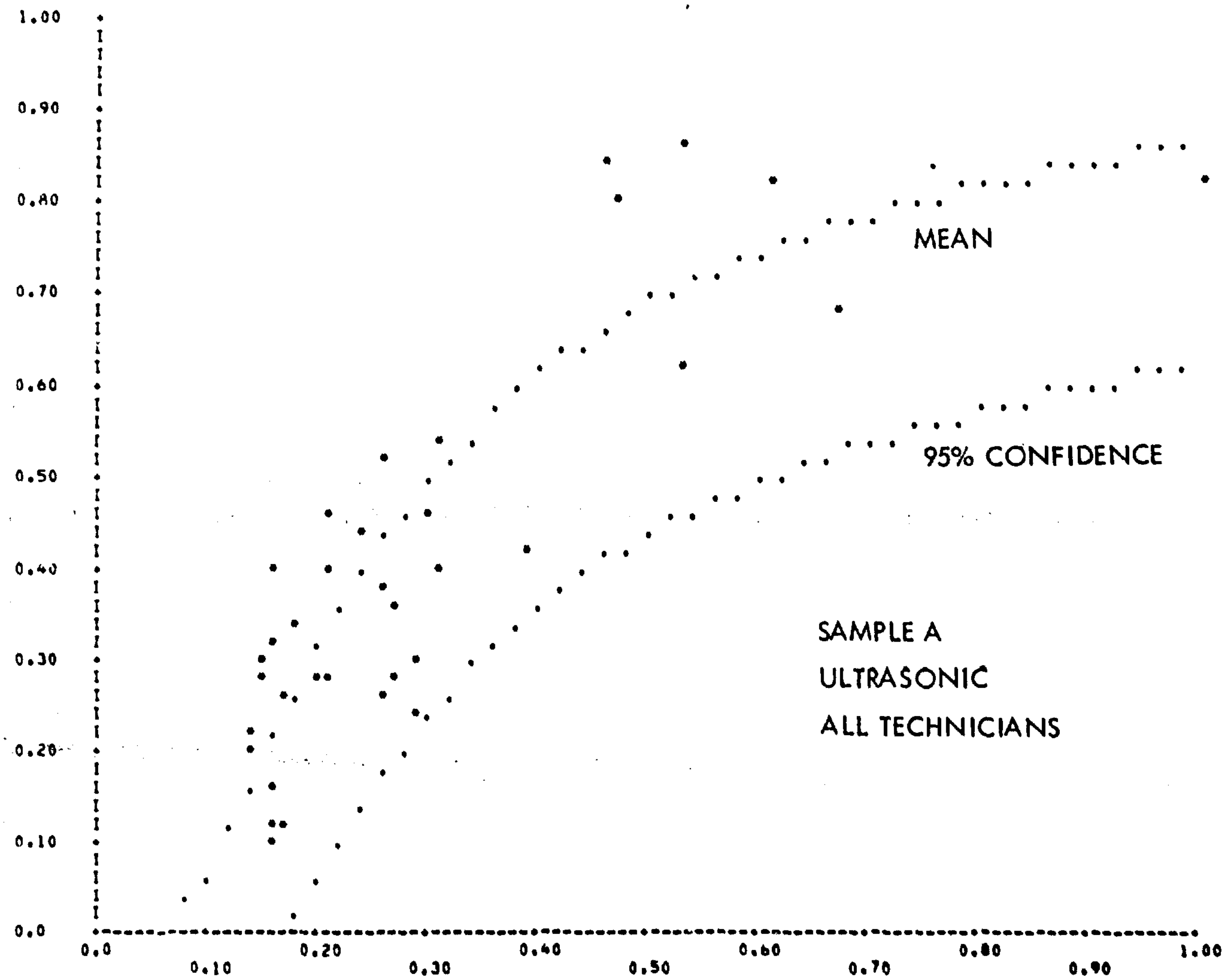


Figure 11-12

SAMPLE: A

METHOD: UT

NO OF INSPECTORS: 27

NO OF FLAWS: 41

INPUT RECORD: 02 A UT 1 35 99 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).

UPPER 50% ALL TECH SAMPLE A (UT)

EQUATION Y=A*X**B A = 0.949428D-02 B = 3.054159

COEFFICIENT OF CORRELATION = 0.684 COEFFICIENT OF DETERMINATION = 0.577

STANDARD ERROR OF ESTIMATE = 0.17

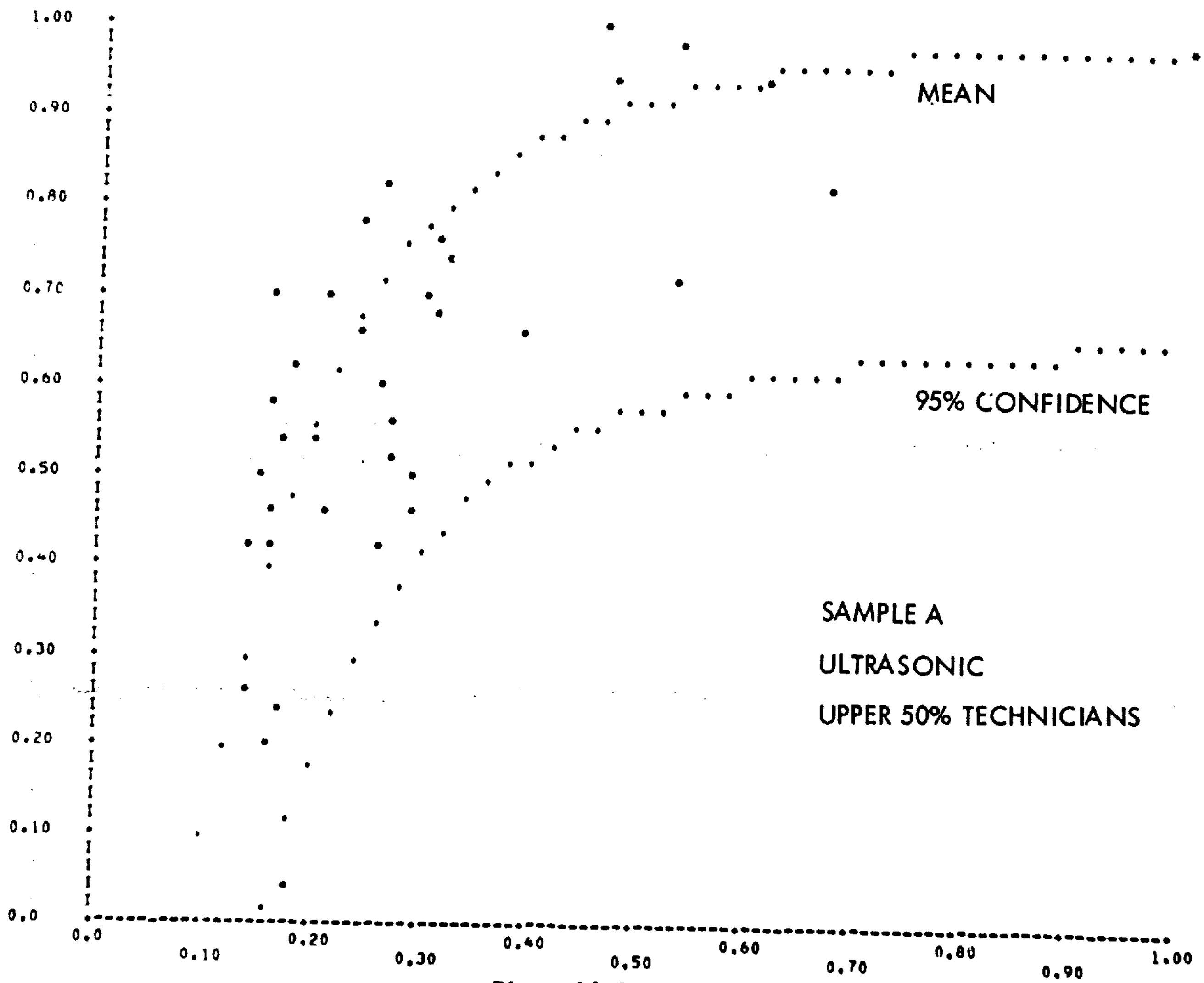


Figure 11-13

SAMPLE: A

METHOD: UT

NO OF INSPECTORS: 21

NO OF FLAWS: 41

INPUT RECORD: 03 A UT 1 D 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).

DEPOT TECH SAMPLE A (UT)

EQUATION Y=A*X**B A = 0.4208580-01 B = 2.364571

COEFFICIENT OF CORRELATION - 0.768 COEFFICIENT OF DETERMINATION - 0.843

STANDARD ERROR OF ESTIMATE - 0.13

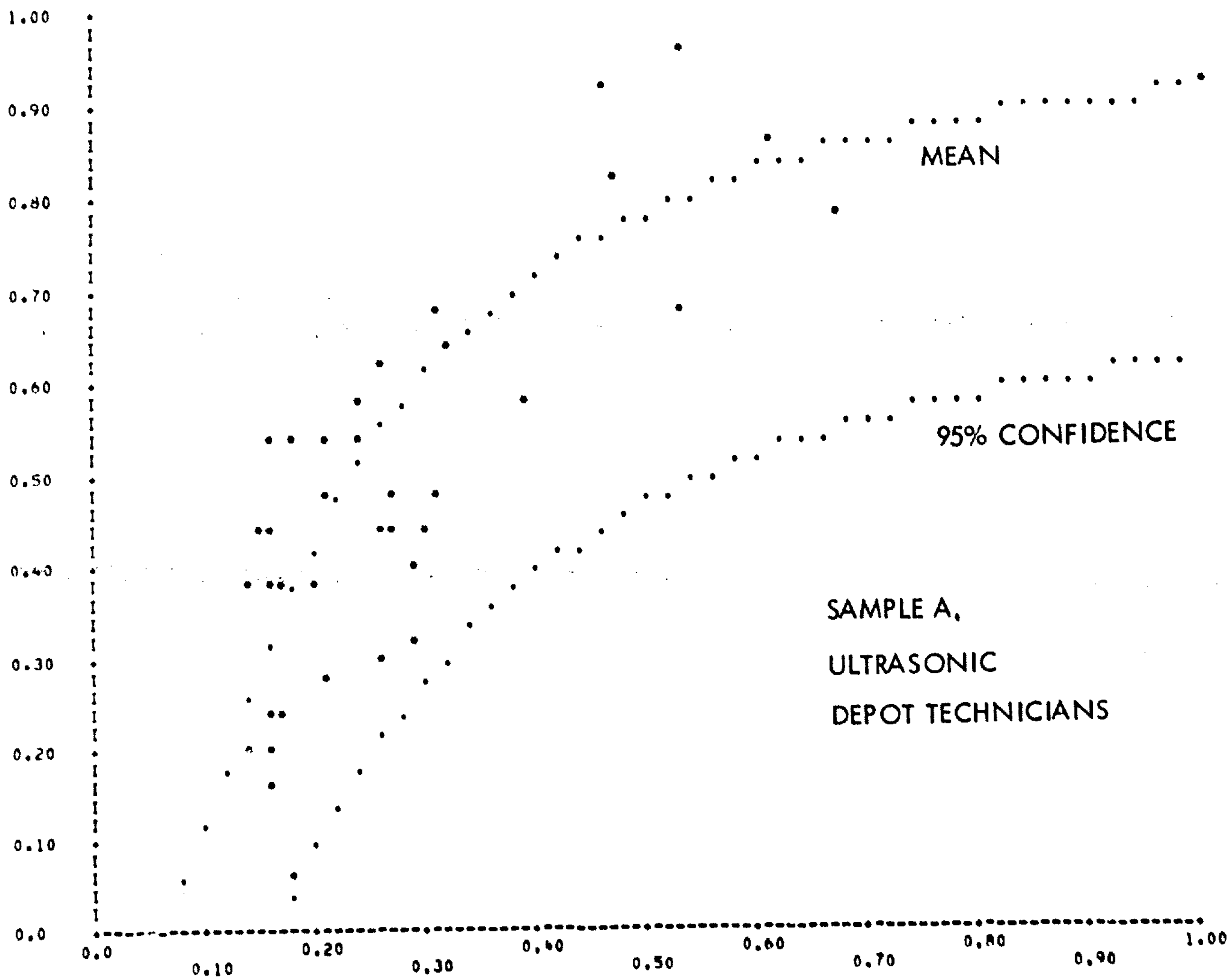


Figure 11-14

SAMPLE: A

METHOD. UT

NO OF INSPECTORS: 43

NO OF FLAWS: 41

INPUT RECORD: 05 A UT 1 5 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).

TECH SKILL LEVEL 5 SAMPLE A (UT)

EQUATION Y=A*X**B A = 0.6905420D-01 B = 2.233066

COEFFICIENT OF CORRELATION = 0.815 COEFFICIENT OF DETERMINATION = 0.890

STANDARD ERROR OF ESTIMATE = 0.11

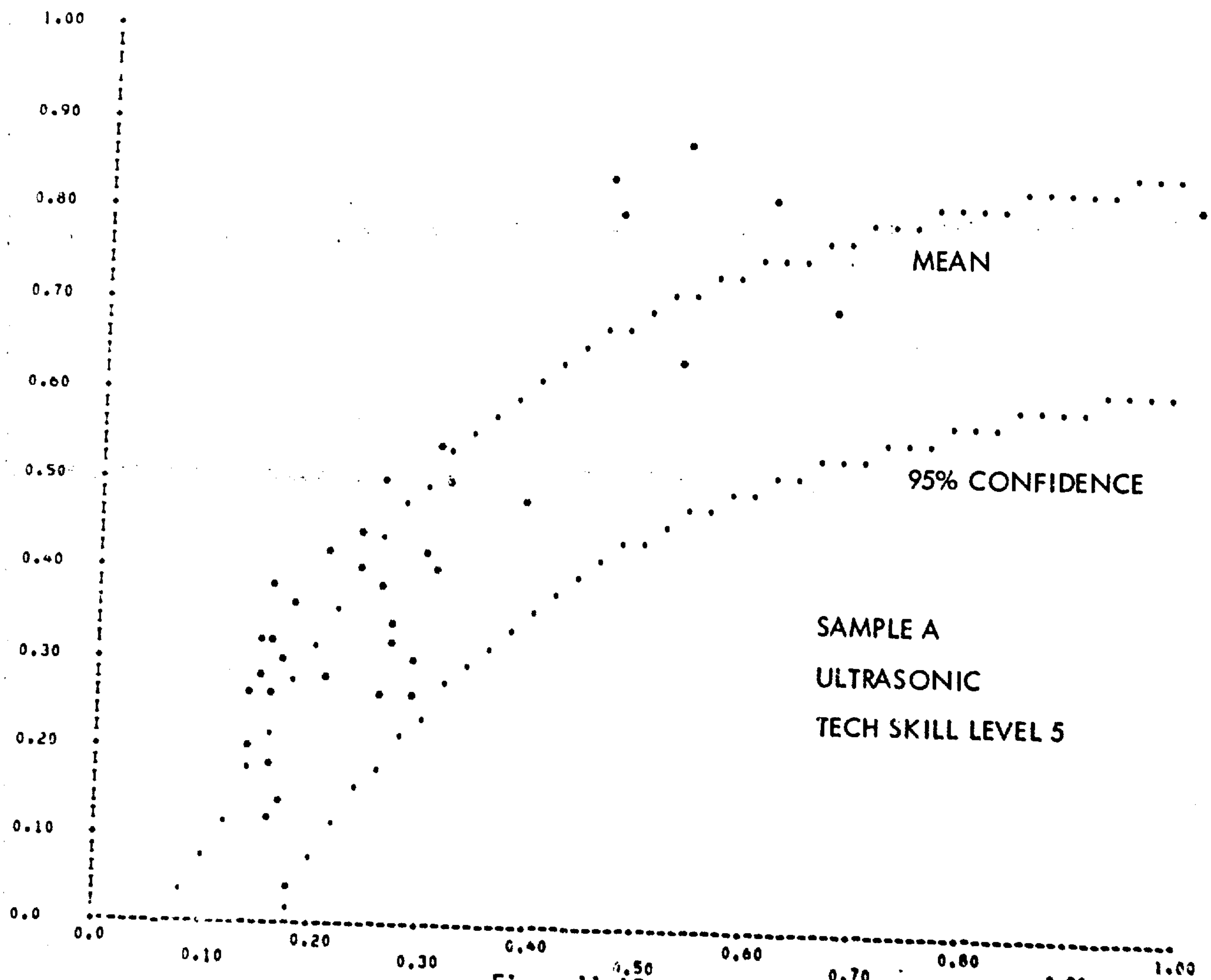


Figure 11-15

SAMPLE: A
METHOD: UT
NO OF INSPECTORS: 10
NO OF FLAWS: 41
INPUT RECORD: 05 A UT 1 7 95 10
CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).
TECH SKILL LEVEL 7 SAMPLE A (UT)

EQUATION Y=A*X**B A = 0.8525080-01 B = 2.237740

COEFFICIENT OF CORRELATION = 0.707 COEFFICIENT OF DETERMINATION = 0.790

STANDARD ERROR OF ESTIMATE = 0.16

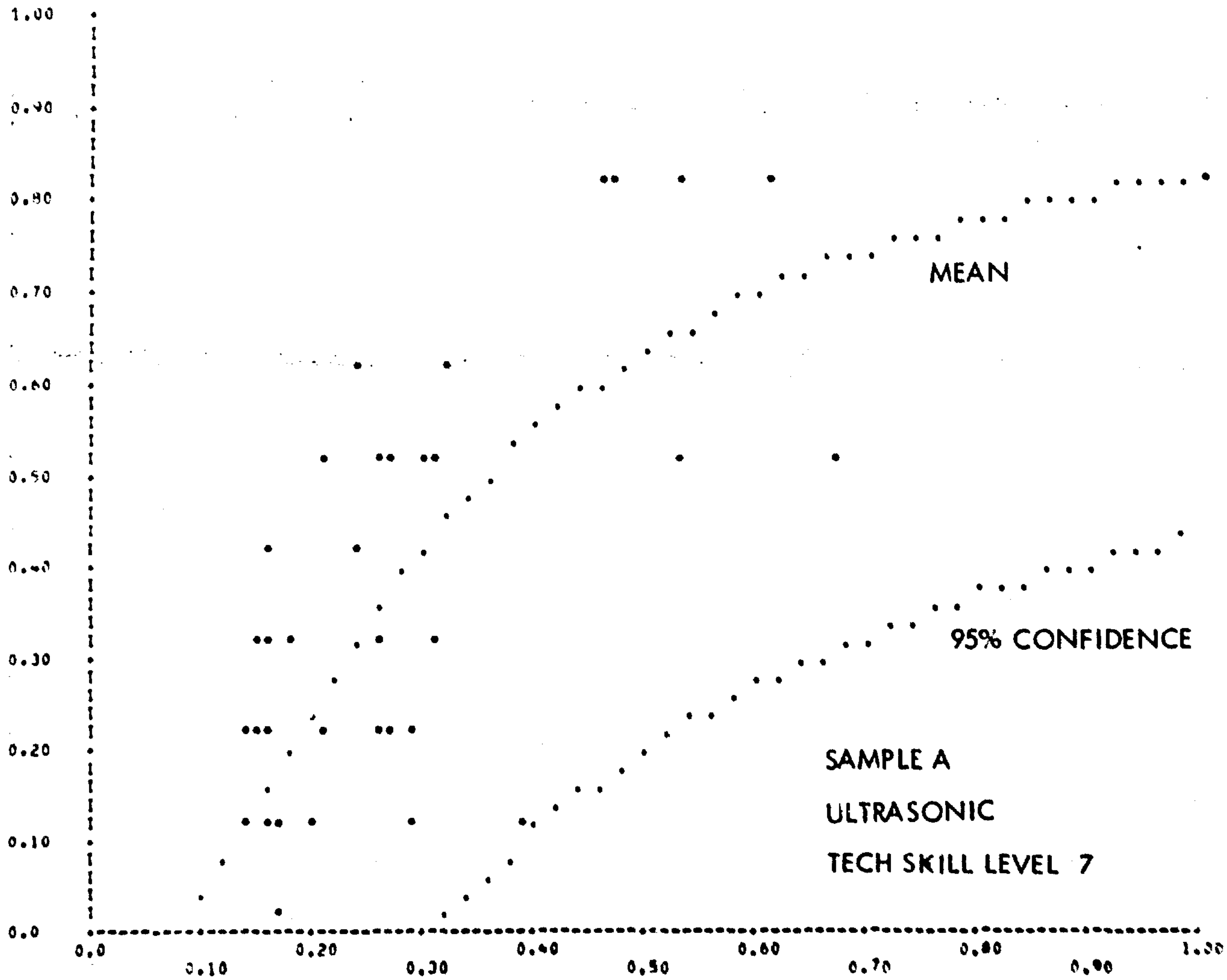


Figure 11-16

SAMPLE: A

METHOD: UT

NO OF INSPECTORS: 17

NO OF FLAWS: 41

INPUT RECORD: 08 A UT 1 150 250 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).

TECH UNDER 25YRS AGE SAMPLE A (UT)

EQUATION Y=A*X**B A = 0.133714 B = 2.071267

COEFFICIENT OF CORRELATION - 0.759

COEFFICIENT OF DETERMINATION - 0.A55

STANDARD ERROR OF ESTIMATE - 0.11

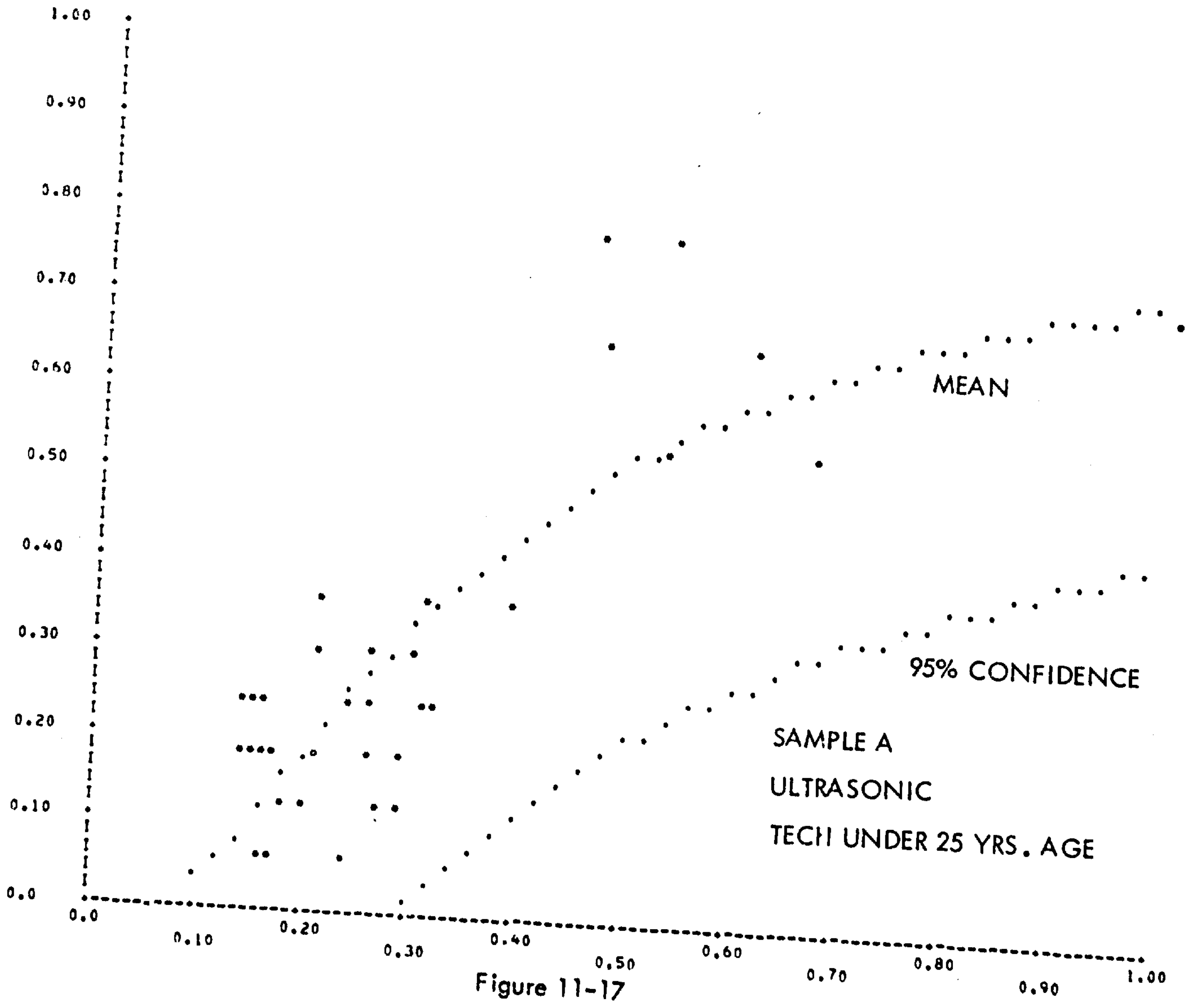


Figure 11-17

SAMPLE: A

METHOD: UT

NO OF INSPECTORS: 12

NO OF FLAWS: 41

INPUT RECORD: 08 A UT 1 400 990 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).

.TECH OVER 40YRS AGE SAMPLE A (UT)

EQUATION Y=A*X**B A = 0.5645200-01 B = 2.350836

COEFFICIENT OF CORRELATION = 0.740 COEFFICIENT OF DETERMINATION = 0.860

STANDARD ERROR OF ESTIMATE = 0.12

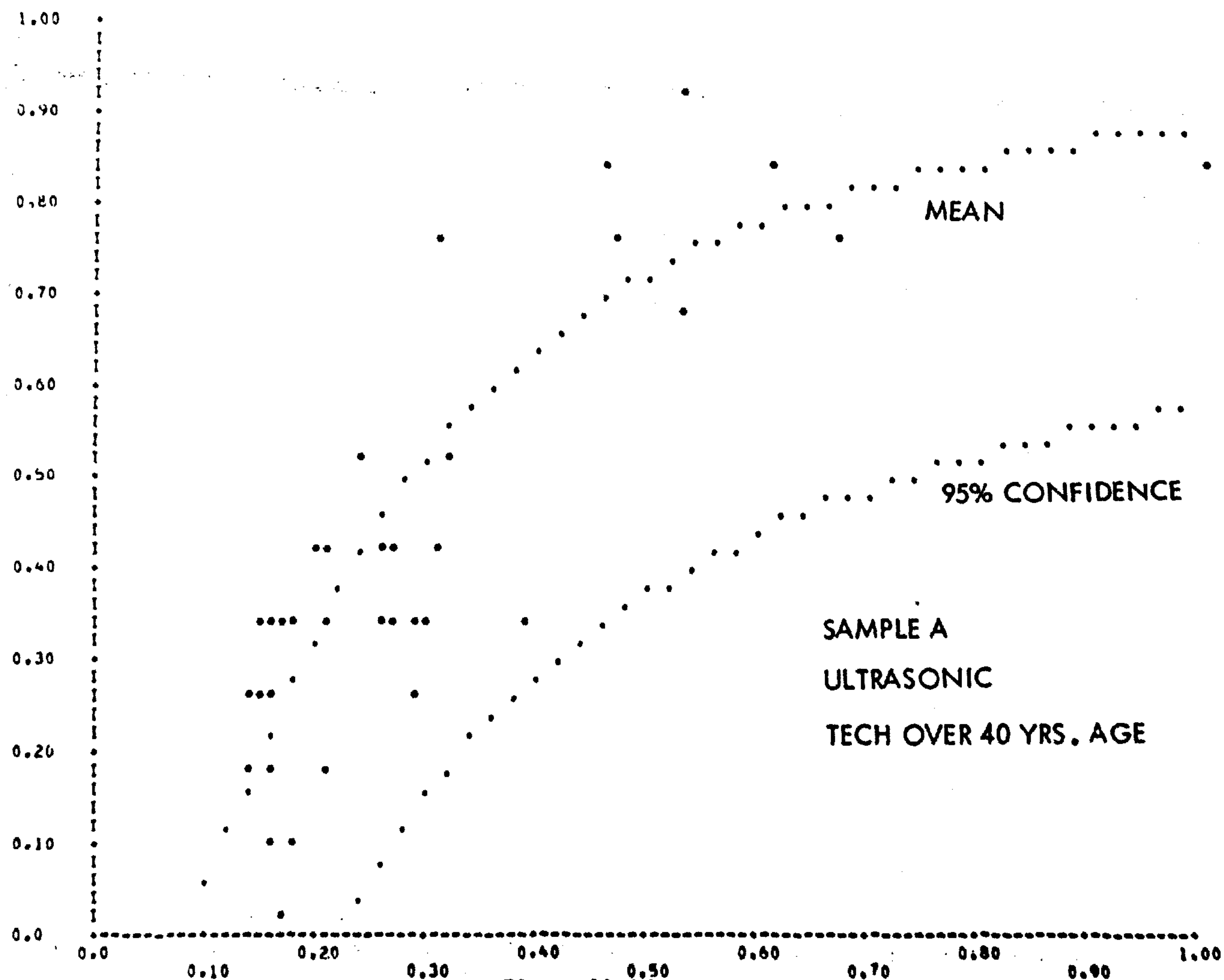


Figure 11-18

SAMPLE: A

METHOD: UT

NO OF INSPECTORS: 52

NO OF FLAWS: 41

INPUT RECORD: 09 A UT 1 011 099 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).

TECH OVER 10 YRS EXPER. SAMPLE A (UT)

EQUATION Y=A*X**B A = 0.7235520-01 B = 2.231294

COEFFICIENT OF CORRELATION = 0.817 COEFFICIENT OF DETERMINATION = 0.890

STANDARD ERROR OF ESTIMATE = 0.11

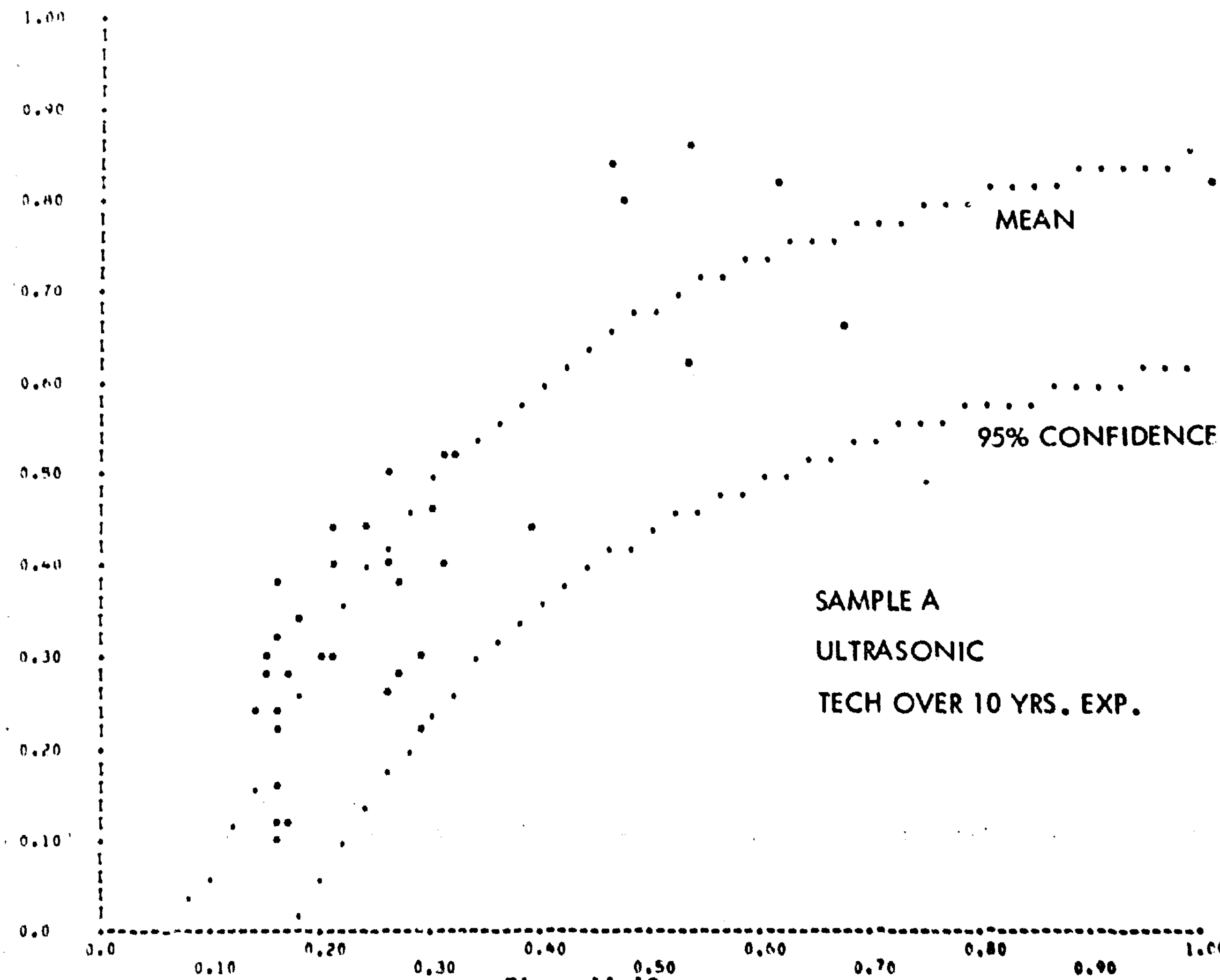


Figure 11-19

SAMPLE: A

METHOD: UT

NO OF INSPECTORS: 17

NO OF FLAWS: 41

INPUT RECORD: 10 A UT 1 000 200 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).

TECH 0-200HRS NDI TRNG SAMPLE A (UT)

EQUATION Y=A*X**B A = 0.1434190-01 B = 2.910792

COEFFICIENT OF CORRELATION = 0.724 COEFFICIENT OF DETERMINATION = 0.563

STANDARD ERROR OF ESTIMATE = 0.16

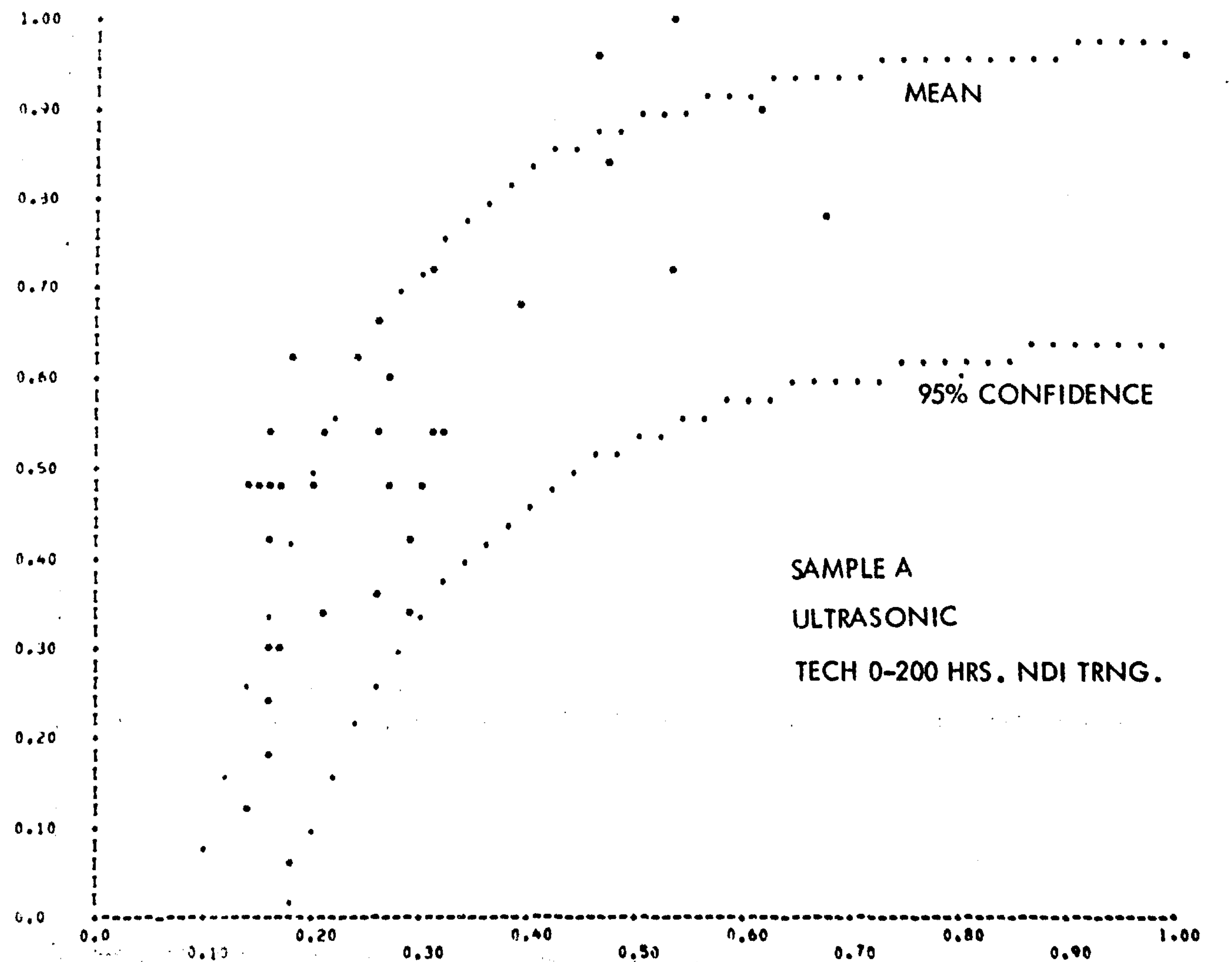


Figure 11-20

SAMPLE: A

METHOD: UT

NO OF INSPECTORS: 10

NO OF FLAWS: 41

INPUT RECORD: 10 A UT 1 500 999 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).

TECH 500+ HRS NDI TRNG SAMPLE A (UT)

EQUATION Y=A*X**B A = 0.111243 B = 2.168064

COEFFICIENT OF CORRELATION - 0.737 COEFFICIENT OF DETERMINATION - 0.827

STANDARD ERROR OF ESTIMATE - 0.13

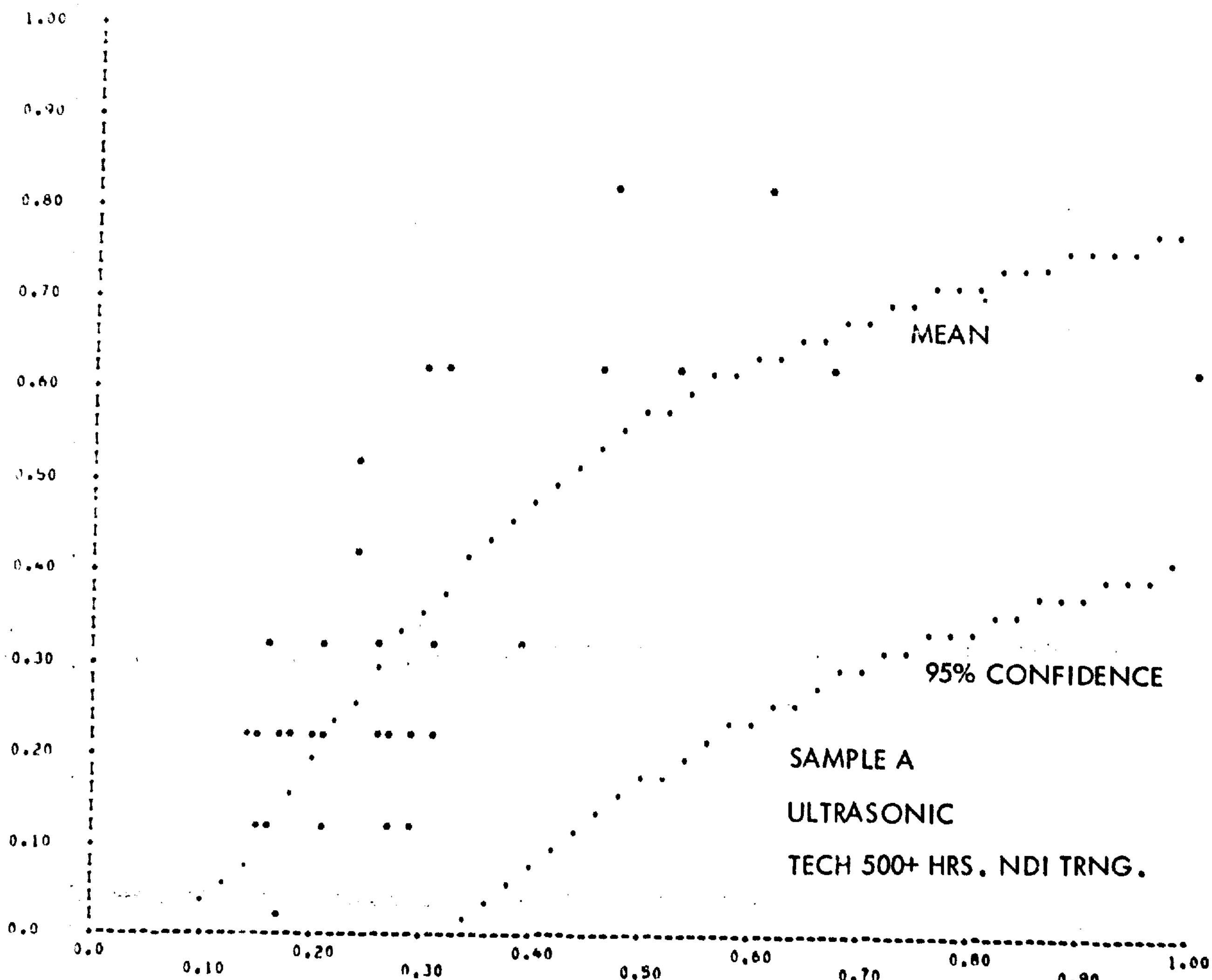


Figure 11-21

SAMPLE: B

METHOD: ET

NO OF INSPECTORS: 94

NO OF FLAWS: 52

INPUT RECORD: 01 B ET 1 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).

ALL TECH. SAMPLE B (ET)

EQUATION Y=A*X**B A = 0.5026130-01 B = 1.741364

COEFFICIENT OF CORRELATION - 0.885 COEFFICIENT OF DETERMINATION - 0.827

STANDARD ERROR OF ESTIMATE - 0.14

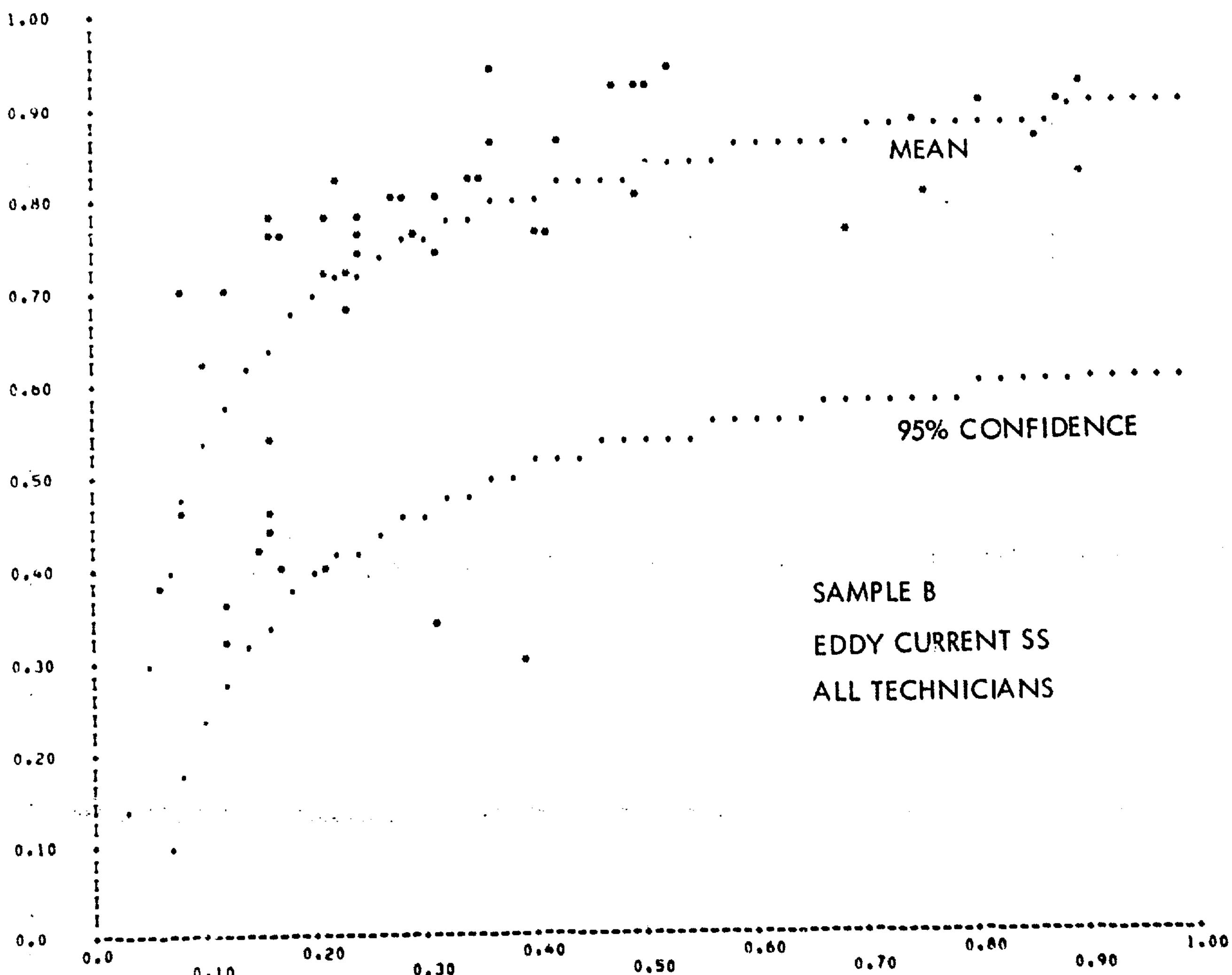


Figure 11-22

SAMPLE: B

METHOD: ET

NO OF INSPECTORS: 48

NO OF FLAWS: 52

INPUT RECORD: 02 B ET 1 75 99 .95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).

UPPER 50% ALL TECH SAMPLE B (ET)

EQUATION Y=A*X**B A = 0.333321D-02 B = 2.698004

COEFFICIENT OF CORRELATION = 0.832 COEFFICIENT OF DETERMINATION = 0.510

STANDARD ERROR OF ESTIMATE = 0.15

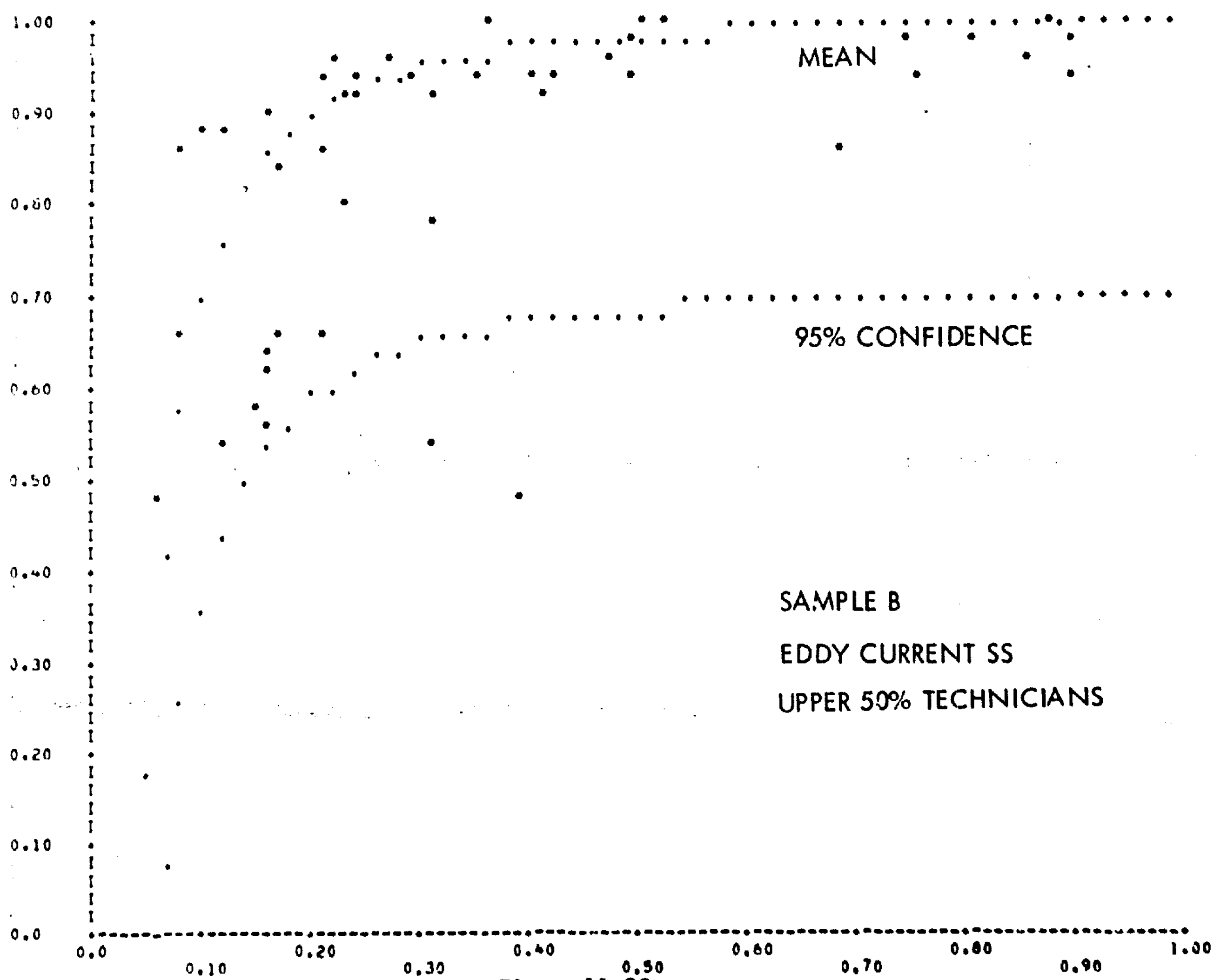


Figure 11-23

SAMPLE: B

METHOD: ET

NO OF INSPECTORS: 40

NO OF FLAWS: 52

INPUT RECORD: 03 B ET 1 D 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).

DEPOT TECH SAMPLE B (ET)

EQUATION Y=A*X**B A = 0.5708860-01 B = 1.590418

COEFFICIENT OF CORRELATION = 0.882 COEFFICIENT OF DETERMINATION = 0.738

STANDARD ERROR OF ESTIMATE = 0.14

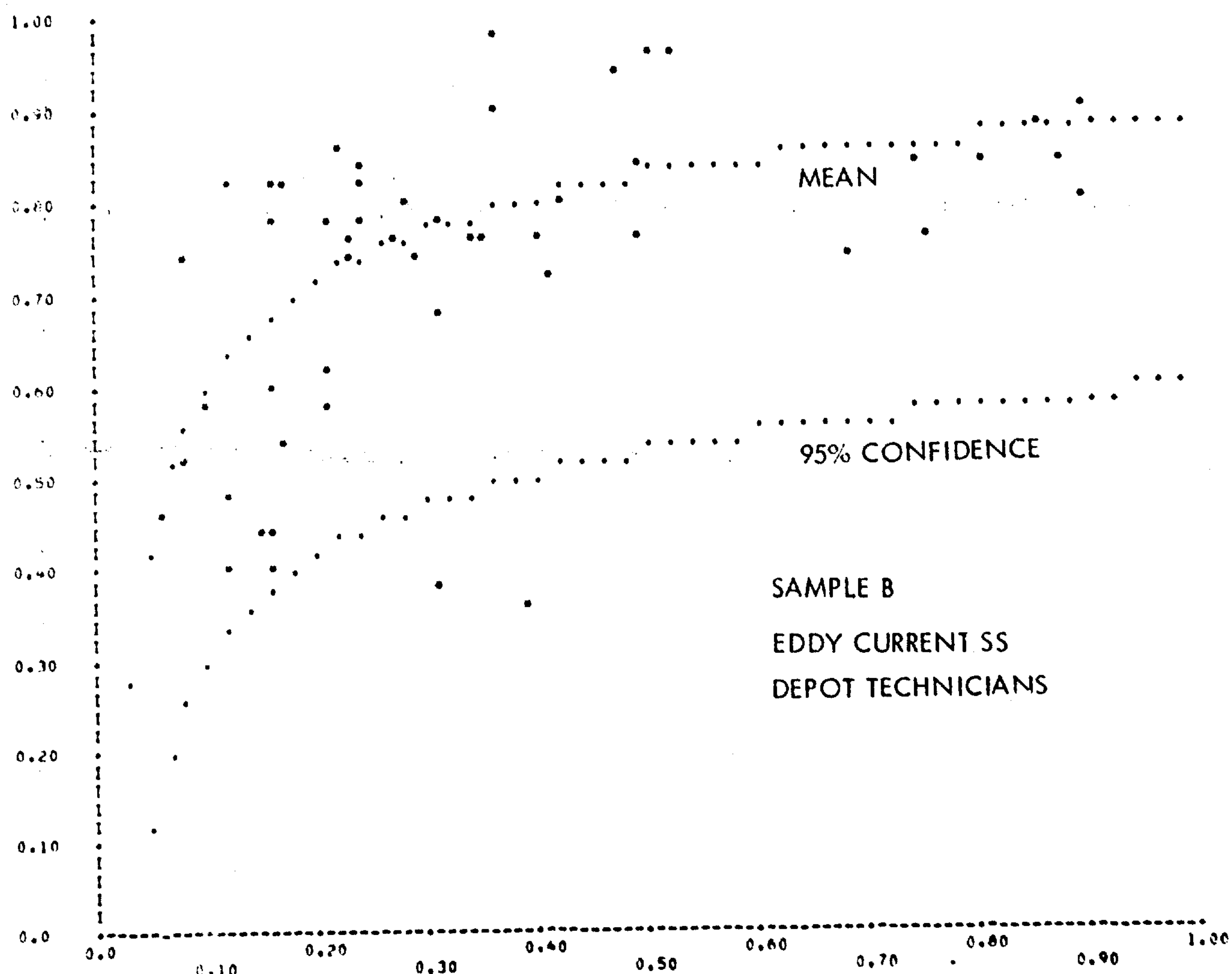


Figure 11-24

SAMPLE: B

METHOD: ET

NO OF INSPECTORS: 73

NO OF FLAWS: 52

INPUT RECORD: 05 B ET 1 5 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).

TECH SKILL LEVEL 5 SAMPLE B (ET)

EQUATION Y=A*X**B A = 0.5682140D-01 B = 1.665944

COEFFICIENT OF CORRELATION = 0.875 COEFFICIENT OF DETERMINATION = 0.794

STANDARD ERROR OF ESTIMATE = 0.15

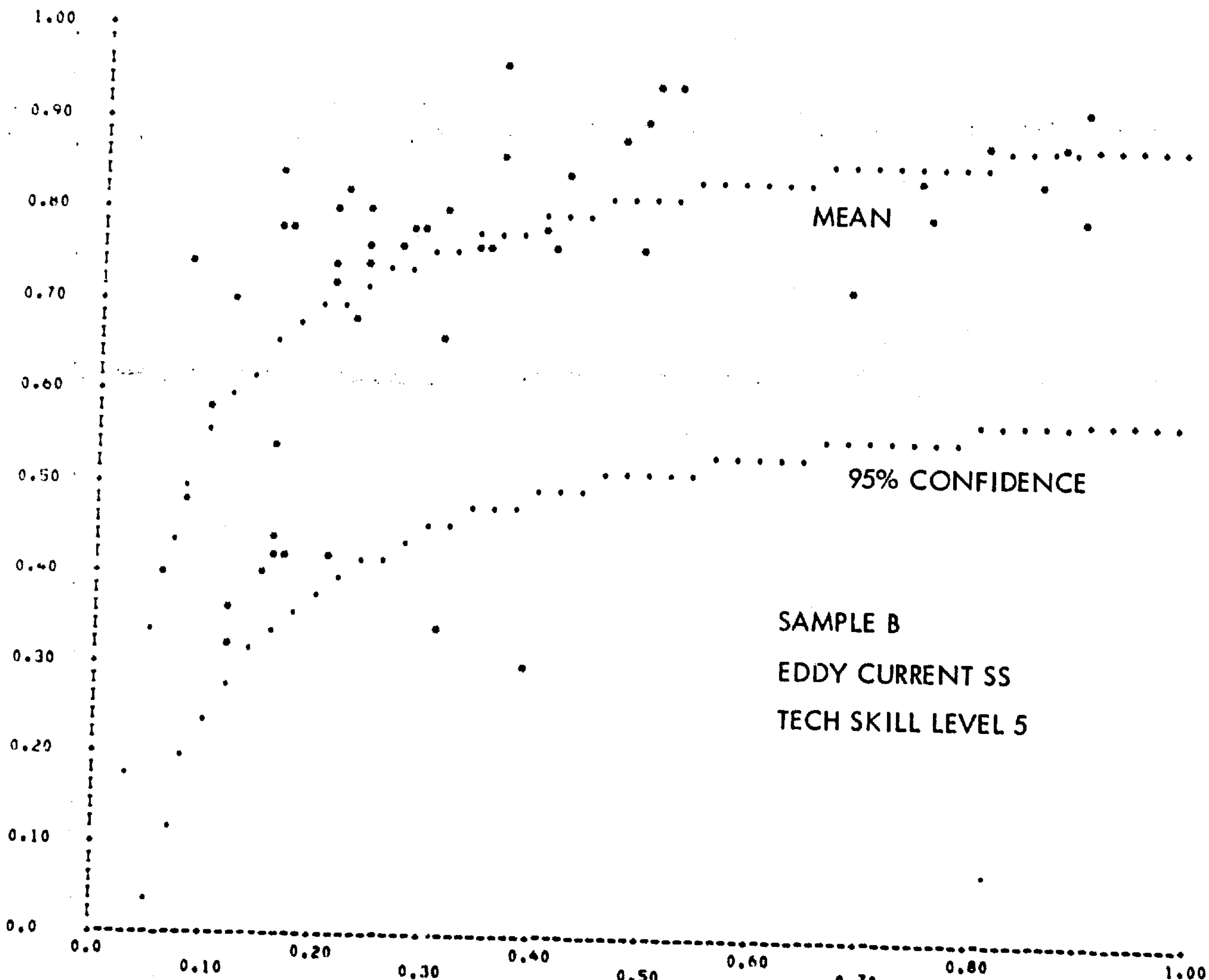


Figure 11-25

SAMPLE: B

METHOD: ET

NO OF INSPECTORS: 14

NO OF FLAWS: 52

INPUT RECORD: 05 B ET 1 7 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).

TECH SKILL LEVEL 7 SAMPLE B (ET)

EQUATION Y=A*X**B A = 0.626500D-02 B = 2.540263

COEFFICIENT OF CORRELATION = 0.809 COEFFICIENT OF DETERMINATION = 0.292

STANDARD ERROR OF ESTIMATE = 0.26

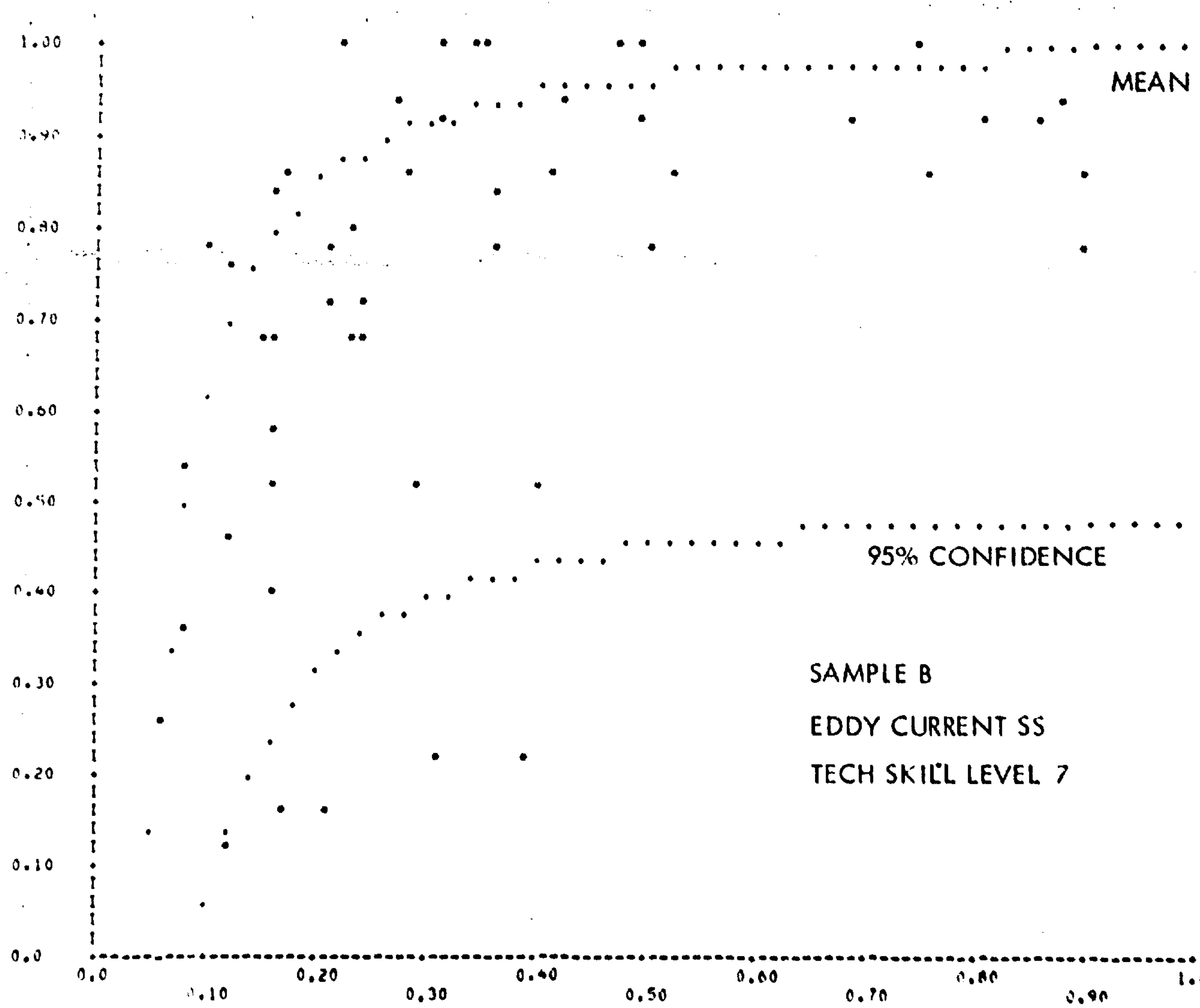


Figure 11-26

SAMPLE: B

METHOD: ET

NO OF INSPECTORS: 6

NO OF FLAWS: 52

INPUT RECORD: 07 B ET 1 N 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).

TECH DID NOT GRAD. HS SAMPLE B (ET)

EQUATION Y=A*X**B A = 0.2020530-01 B = 1.386033

COEFFICIENT OF CORRELATION = 0.612 COEFFICIENT OF DETERMINATION = 0.6700-01

STANDARD ERROR OF ESTIMATE = 0.36

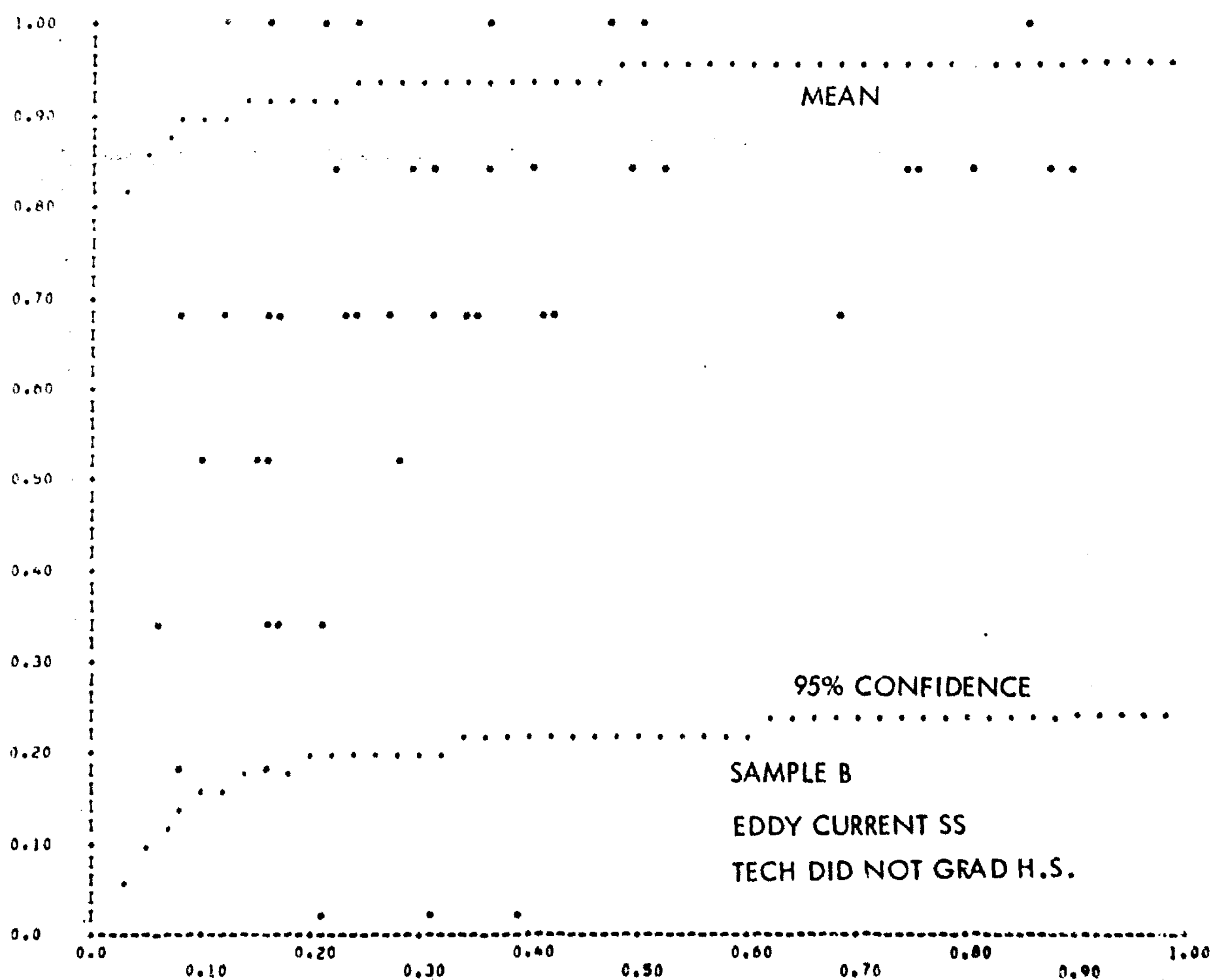


Figure 11-27

SAMPLE: B

METHOD: ET

NO OF INSPECTORS: 28

NO OF FLAWS: 52

INPUT RECORD: 08 B ET 1 150 250 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).

TECH UNDER 25YRS AGE SAMPLE B (ET)

EQUATION Y=A*X**B A = 0.2518080D-01 B = 2.189283

COEFFICIENT OF CORRELATION = 0.874 COEFFICIENT OF DETERMINATION = 0.600

STANDARD ERROR OF ESTIMATE = 0.18

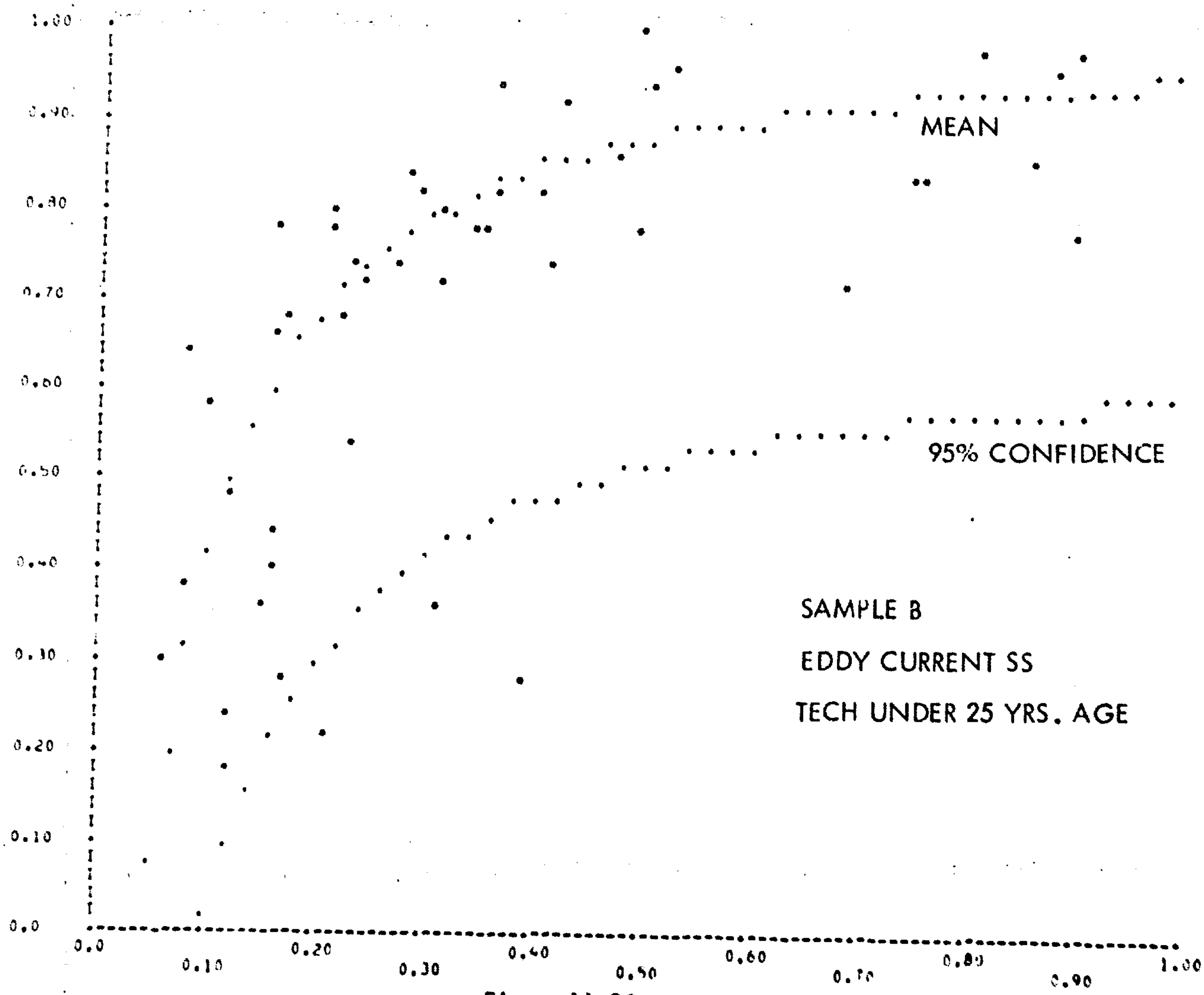


Figure 11-28

SAMPLE: B

METHOD: ET

NO OF INSPECTORS: 29

NO OF FLAWS: 52

INPUT RECORD: 08 B ET 1 400 990 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).

TECH OVER 40YRS AGE SAMPLE B (ET)

EQUATION Y=A*X**B A = 0.4330540D-01 B = 1.794036

COEFFICIENT OF CORRELATION - 0.683 COEFFICIENT OF DETERMINATION - 0.718

STANDARD ERROR OF ESTIMATE - 0.19

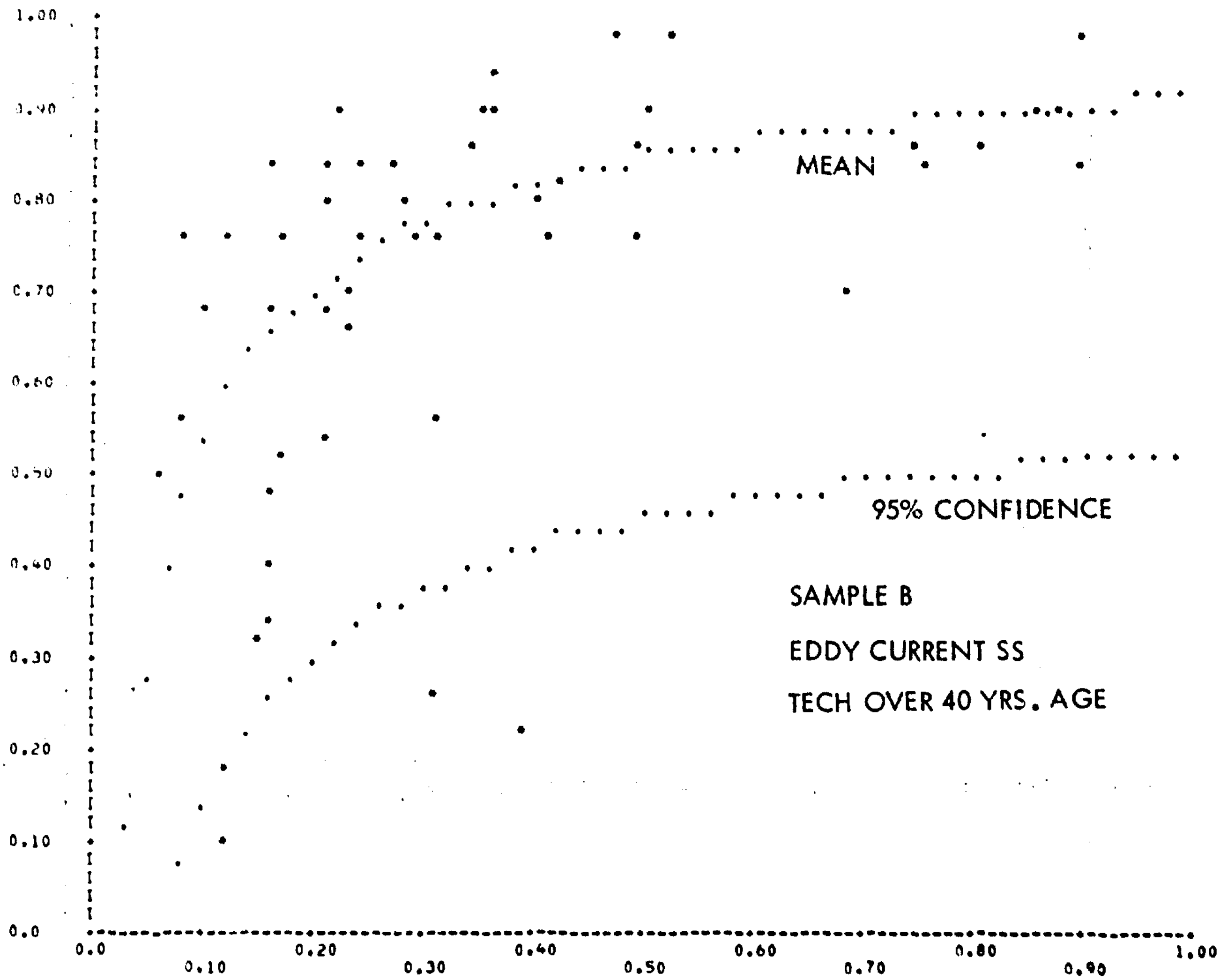


Figure 11-29

SAMPLE: B

METHOD: ET

NO OF INSPECTORS: 22

NO OF FLAWS: 52

INPUT RECORD: 09 B ET 1 000 003 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).

TECH 3YRS OR LESS EXPER. SAMPLE B (ET)

EQUATION Y=A*X**B A = 0.4013940-01 B = 1.841984

COEFFICIENT OF CORRELATION - 0.856 COEFFICIENT OF DETERMINATION - 0.789

STANDARD ERROR OF ESTIMATE - 0.14

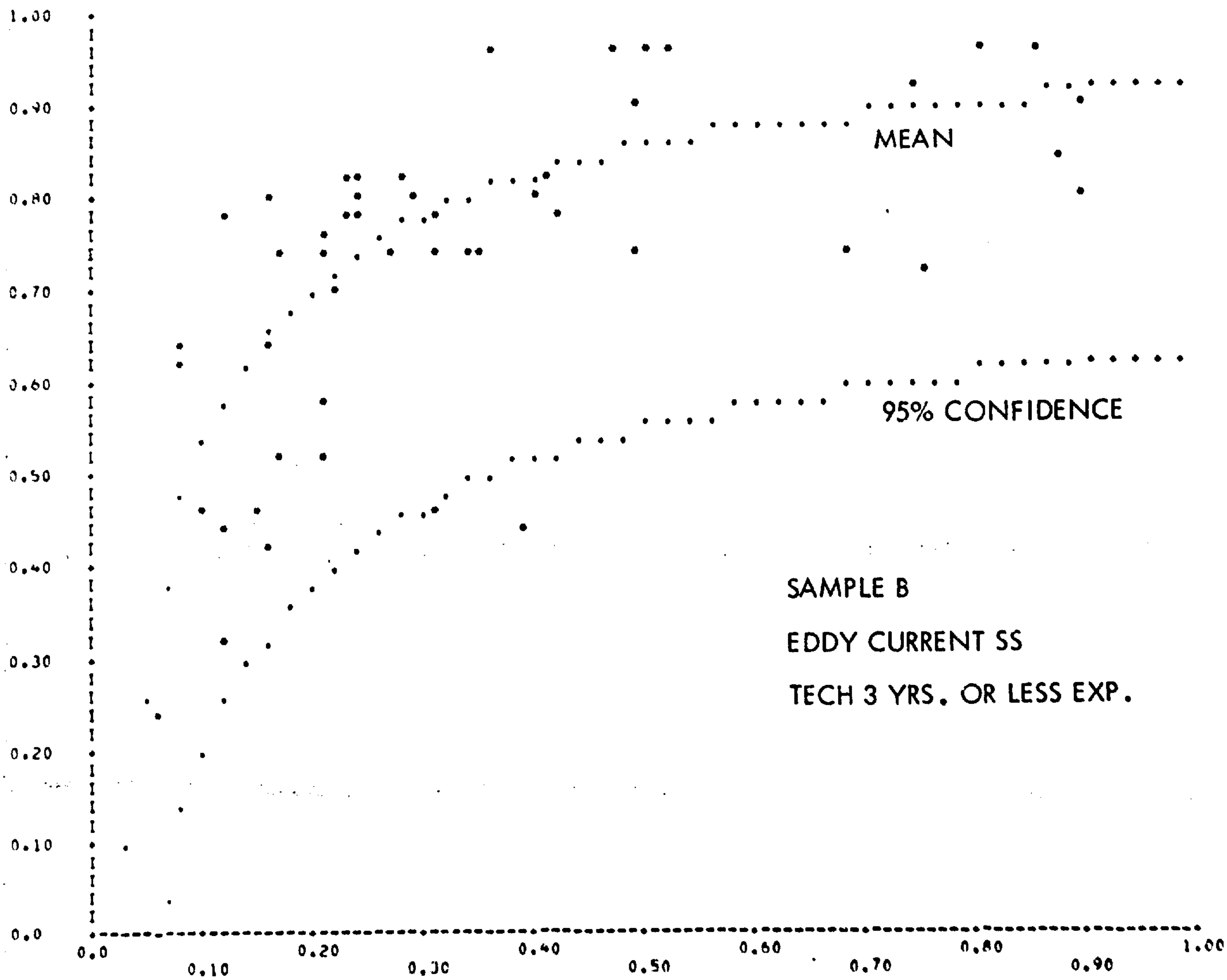


Figure 11-30

SAMPLE: B

METHOD: ET

NO OF INSPECTORS: 62

NO OF FLAWS: 52

INPUT RECORD: 09 8 ET 1 011 099 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).

TECH OVER 10 YRS EXPER. SAMPLE B (ET)

EQUATION Y=A*X**B A = 0.4459580-01 B = 1.814352

COEFFICIENT OF CORRELATION = 0.865 COEFFICIENT OF DETERMINATION = 0.819

STANDARD ERROR OF ESTIMATE = 0.16

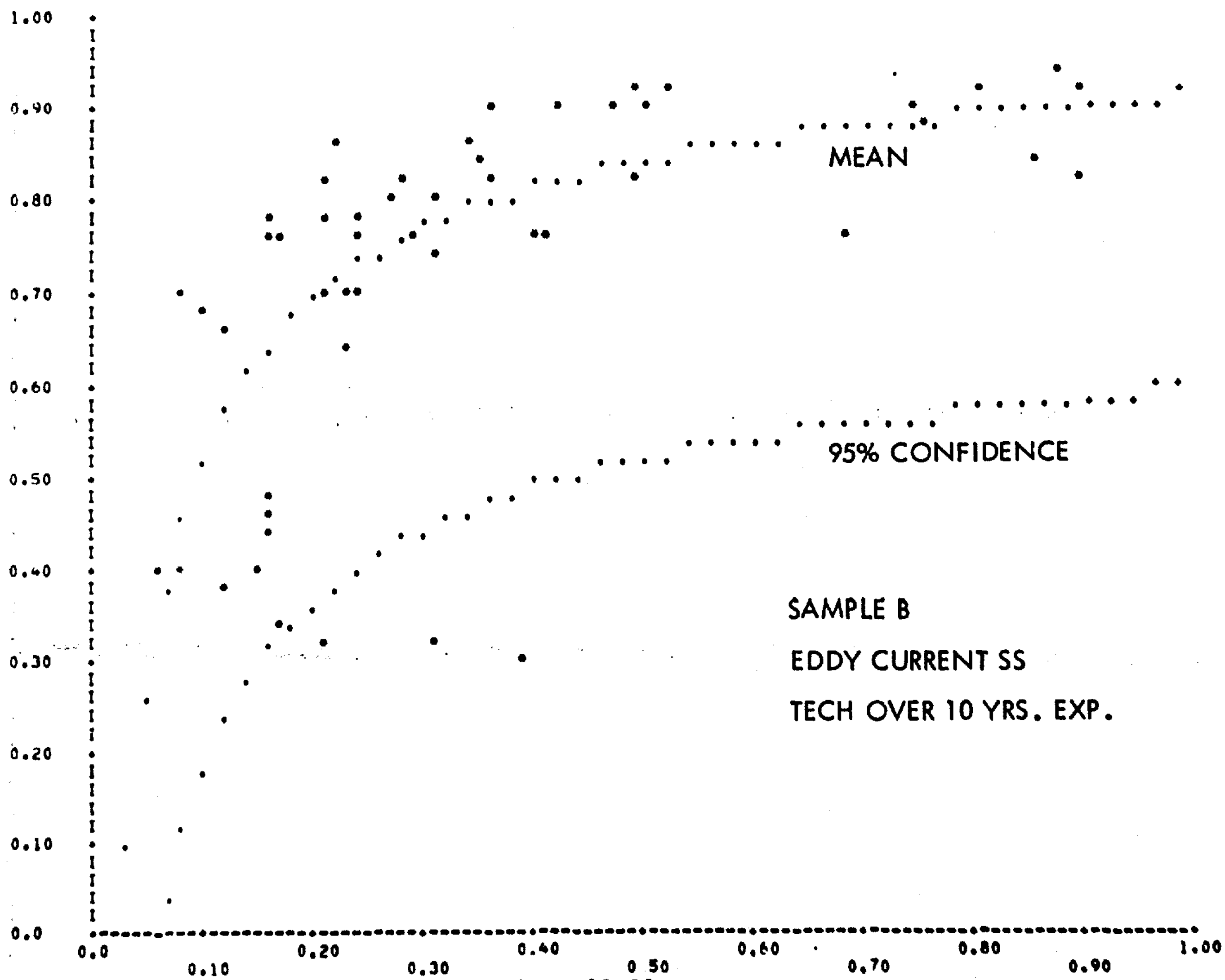


Figure 11-31

SAMPLE: B

METHOD: ET

NO OF INSPECTORS: 39

NO OF FLAWS: 52

INPUT RECORD: 10 B ET 1 000 200 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).

TECH 0-200HRS NDI TRNG SAMPLE B (ET)

EQUATION Y=A*X**B A = 0.580366D-01 B = 1.587147

COEFFICIENT OF CORRELATION - 0.881 COEFFICIENT OF DETERMINATION - 0.742

STANDARD ERROR OF ESTIMATE - 0.14

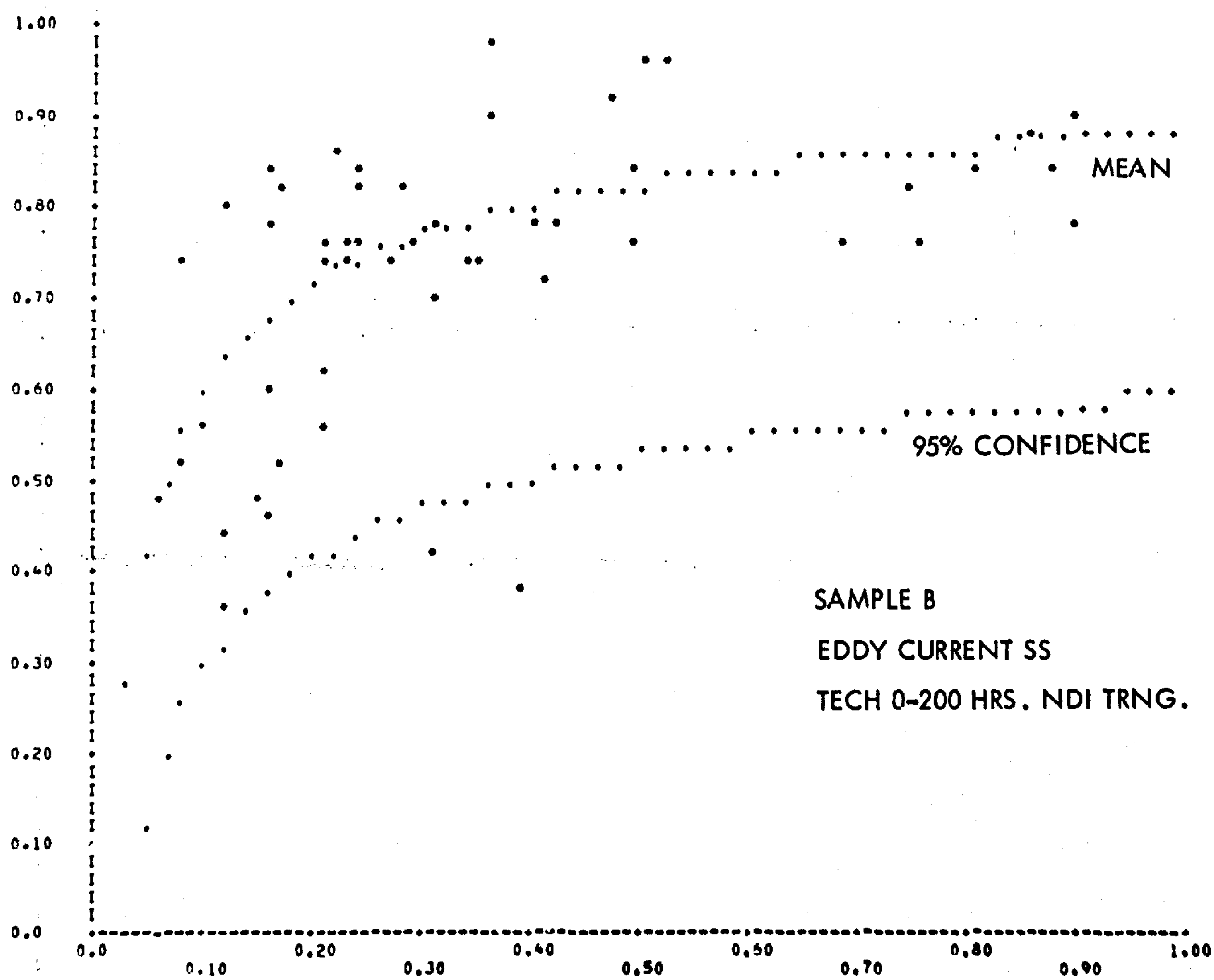


Figure 11-32

SAMPLE: B

METHOD: ET

NO OF INSPECTORS: 18

NO OF FLAWS: 52

INPUT RECORD: 10 B ET 1 500 999 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).

TECH 500+ HRS NDI TRNG SAMPLE B (ET)

EQUATION Y=A*X**B A = 0.5446930-02 B = 2.671400

COEFFICIENT OF CORRELATION = 0.762 COEFFICIENT OF DETERMINATION = 0.357

STANDARD ERROR OF ESTIMATE = 0.26

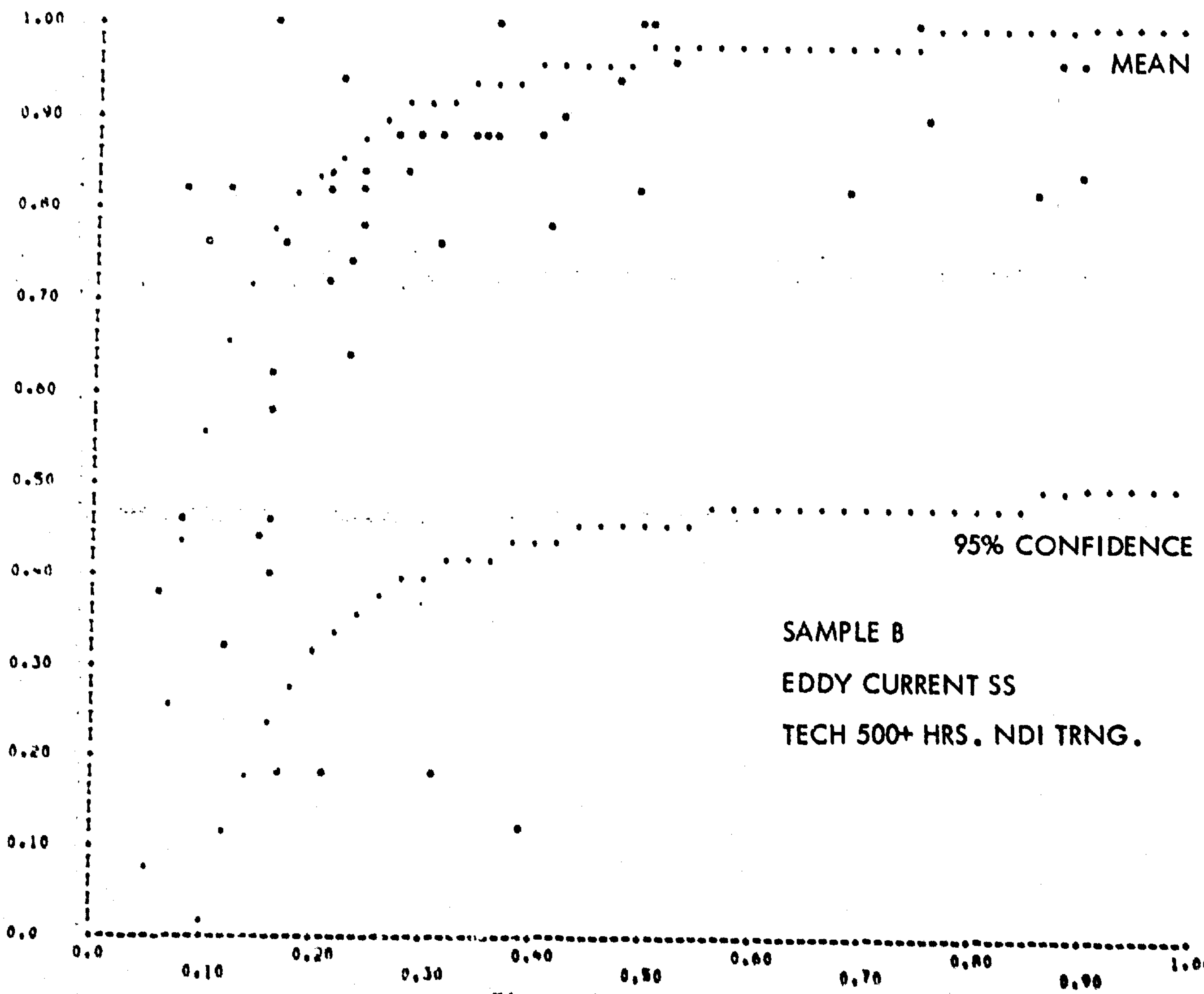


Figure 11-33

SAMPLE: B

METHOD: RT

NO OF INSPECTORS: 59

NO OF FLAWS: 52

INPUT RECORD: 01 B RT 1 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).

ALL TECH. SAMPLE B (RT)

EQUATION Y=A*X**B A = 0.8354380-01 B = 2.196865

COEFFICIENT OF CORRELATION = 0.842 COEFFICIENT OF DETERMINATION = 0.699

STANDARD ERROR OF ESTIMATE = 0.24

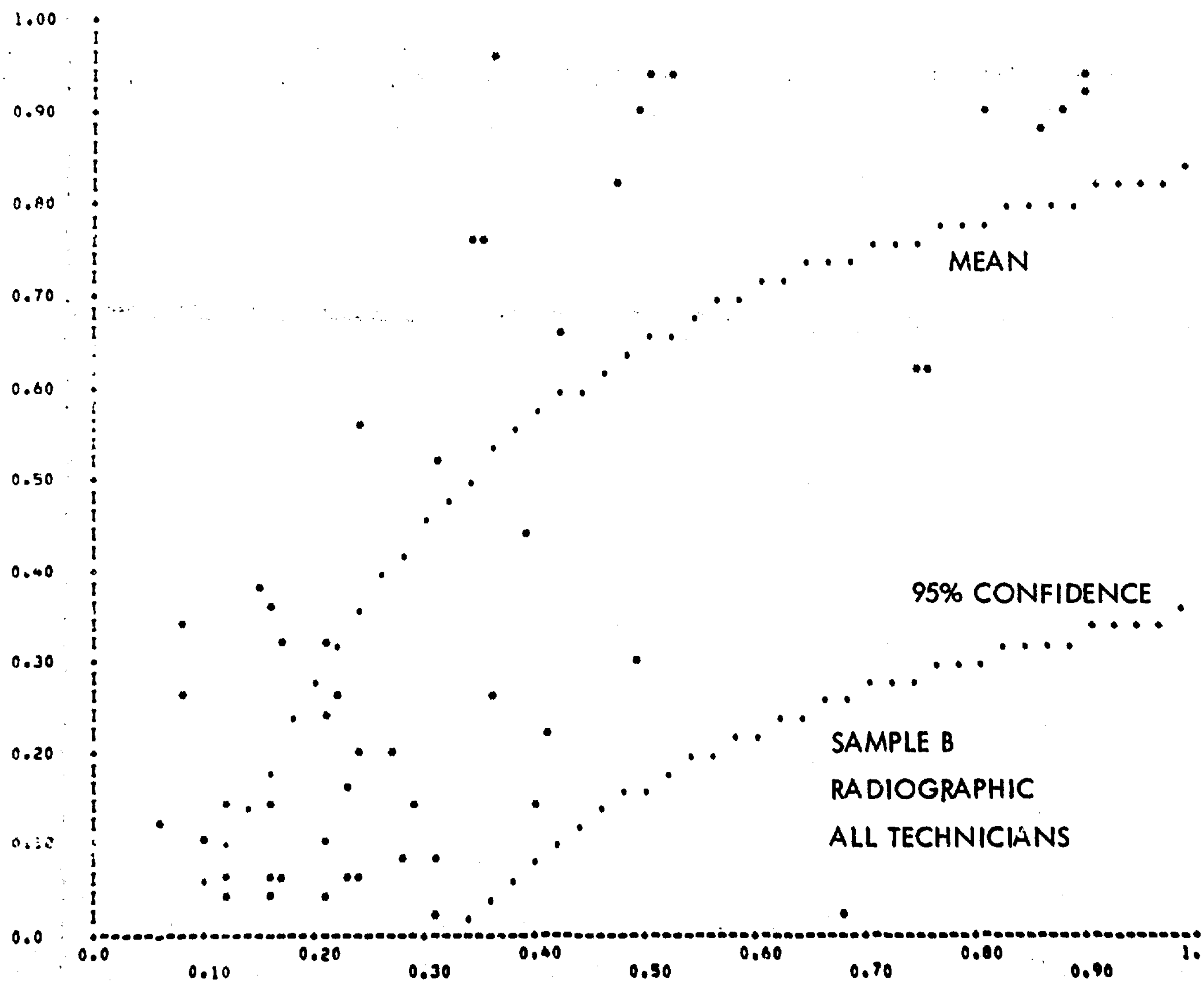


Figure 11-34

SAMPLE: B
METHOD: RT
NO OF INSPECTORS: 23
NO OF FLAWS: 52
INPUT RECORD: 03 B RT 1 D 95 10
CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).
DEPOT TECH SAMPLE B (RT)

EQUATION Y=A*X**B A = 0.138011 B = 1.903342

COEFFICIENT OF CORRELATION = 0.848 COEFFICIENT OF DETERMINATION = 0.738

STANDARD ERROR OF ESTIMATE = 0.22

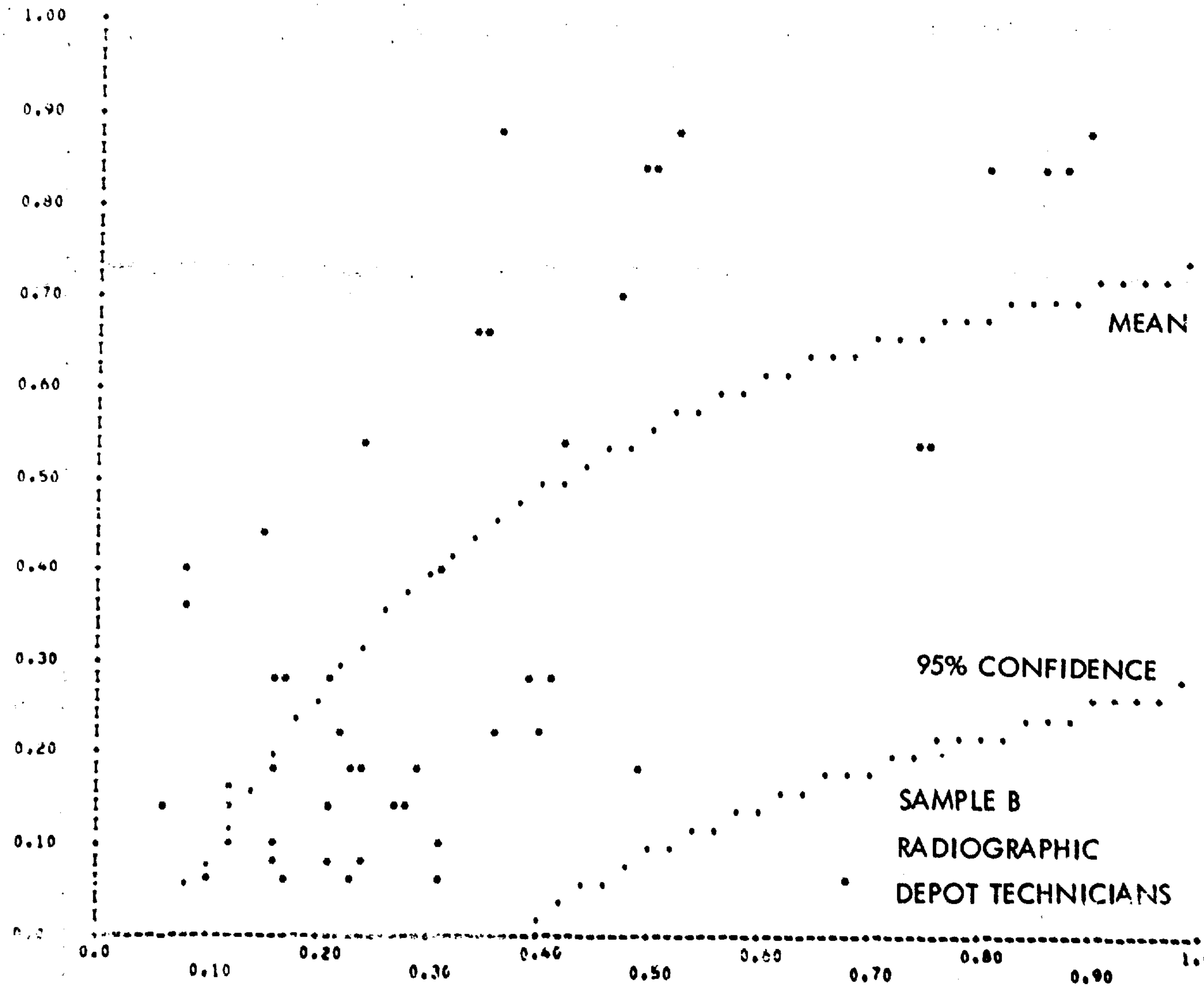


Figure 11-35

SAMPLE: B

METHOD: RT

NO OF INSPECTORS: 42

NO OF FLAWS: 52

INPUT RECORD: 05 8 RT 1 5 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).

TECH SKILL LEVEL 5 SAMPLE B (RT)

EQUATION Y=A*X**B A = 0.884264D-01 B = 2.154389

COEFFICIENT OF CORRELATION = 0.854 COEFFICIENT OF DETERMINATION = 0.715

STANDARD ERROR OF ESTIMATE = 0.23

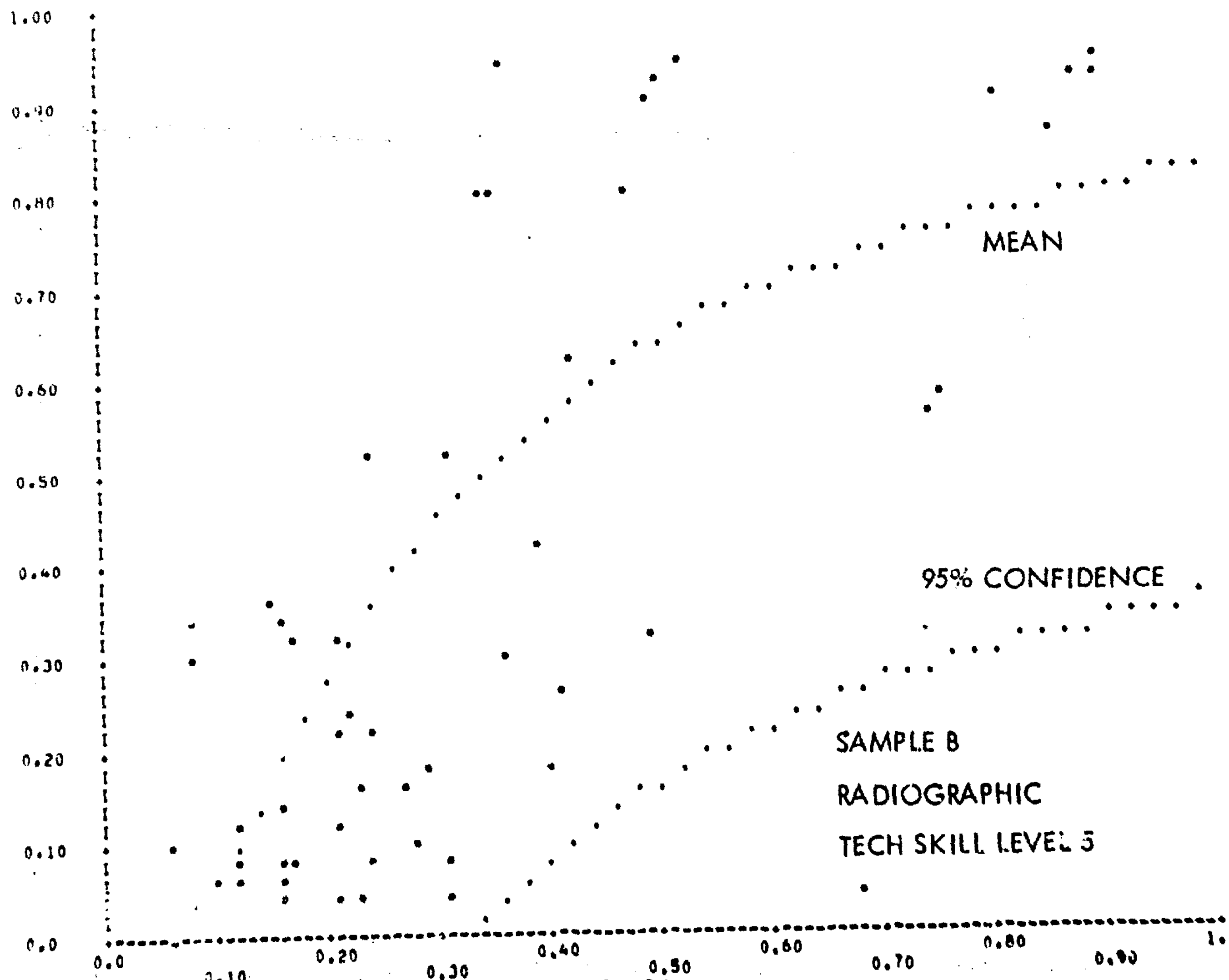


Figure 11-36

SAMPLE: B

METHOD: RT

NO OF INSPECTORS: 14

NO OF FLAWS: 52

INPUT RECORD: 05 B RT 1 7 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).

TECH SKILL LEVEL 7 SAMPLE B (RT)

EQUATION Y=A*X**B A = 0.470113D-01 B = 2.501230

COEFFICIENT OF CORRELATION = 0.677 COEFFICIENT OF DETERMINATION = 0.424

STANDARD ERROR OF ESTIMATE = 0.29

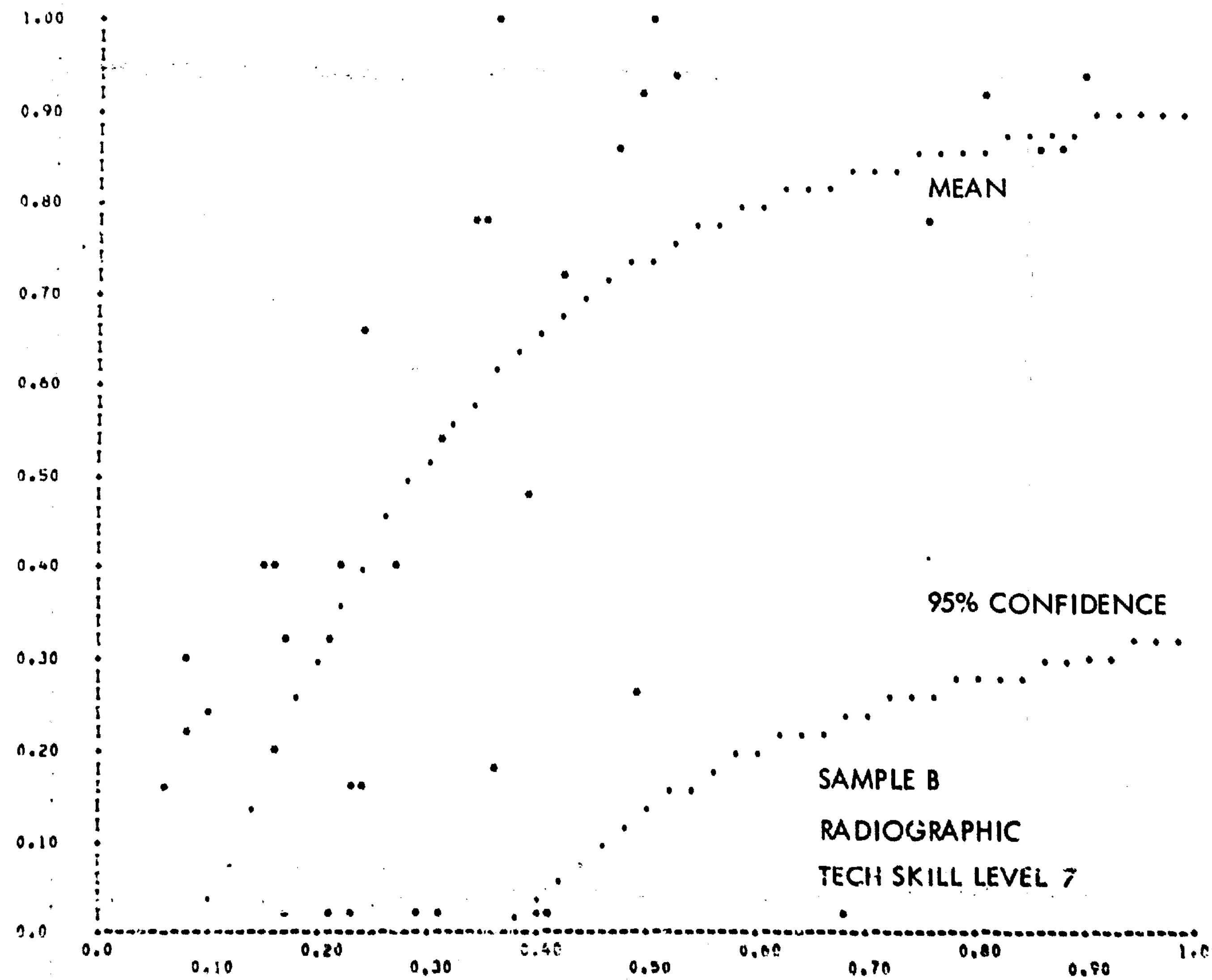


Figure 11-37

SAMPLE: B

METHOD: RT

NO OF INSPECTORS: 20

NO OF FLAWS: 52

INPUT RECORD: 08 B RT 1 400 990 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).

TECH OVER 40YRS AGE SAMPLE B (RT)

EQUATION Y=A*X**B A = 0.141179 B = 1.995176

COEFFICIENT OF CORRELATION = 0.713 COEFFICIENT OF DETERMINATION = 0.680

STANDARD ERROR OF ESTIMATE = 0.23

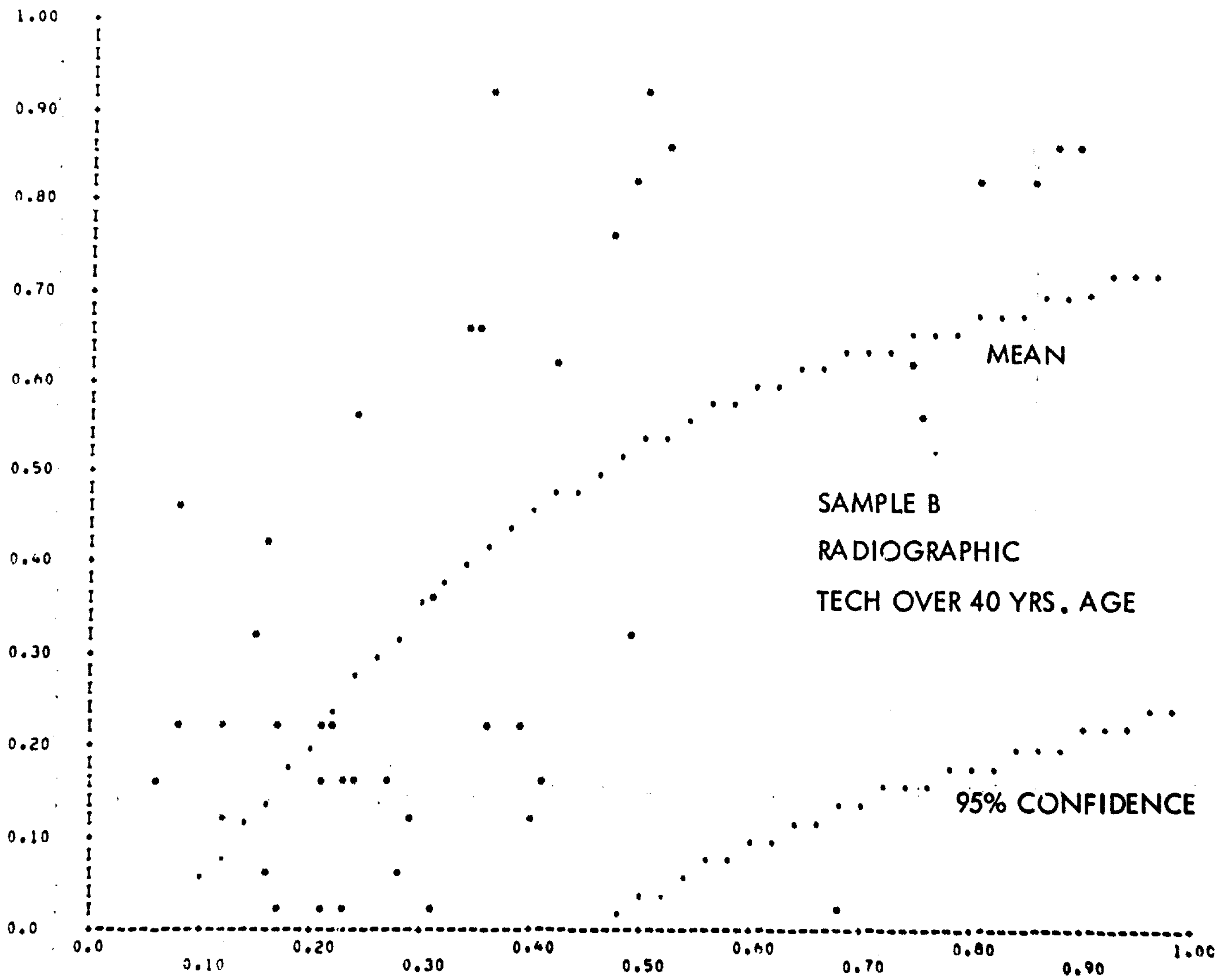


Figure 11-38

SAMPLE: B

METHOD: RT

NO OF INSPECTORS: 44

NO OF FLAWS: 52

INPUT RECORD: 09 B RT 1 011 099 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).

TECH OVER 10 YRS EXPER. SAMPLE B (RT)

EQUATION Y=A*X**B A = 0.7049510-01 B = 2.269053

COEFFICIENT OF CORRELATION - 0.852 COEFFICIENT OF DETERMINATION - 0.696

STANDARD ERROR OF ESTIMATE - 0.25

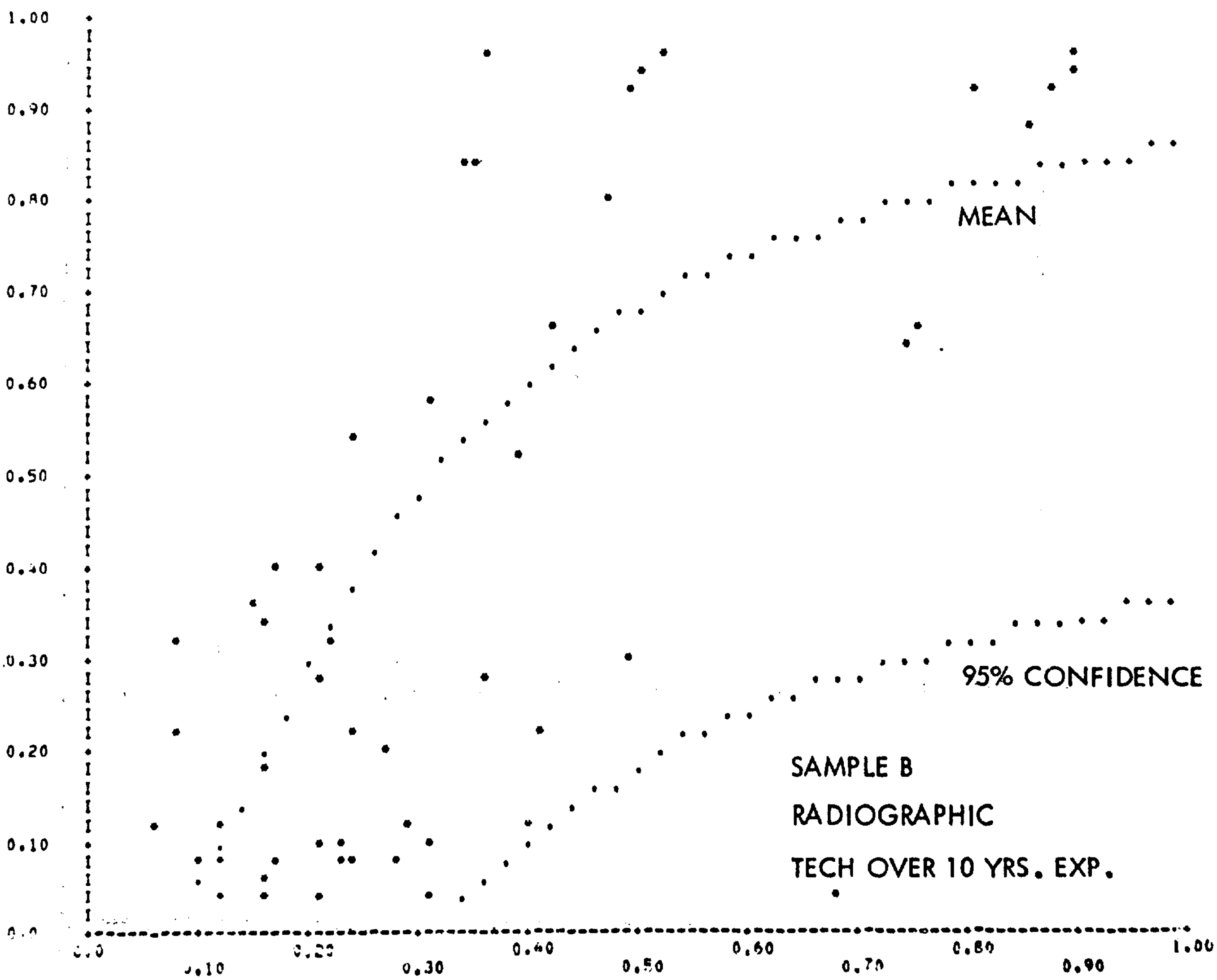


Figure 11-39

SAMPLE: B

METHOD: RT

NO OF INSPECTORS: 12

NO OF FLAWS: 52

INPUT RECORD: 10 B RT 1 000 200 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).

TECH 0-200HRS NDI TRNG SAMPLE B (RT)

EQUATION Y=A*X**B A = 0.4907700-01 B = 2.353024

COEFFICIENT OF CORRELATION = 0.867 COEFFICIENT OF DETERMINATION = 0.458

STANDARD ERROR OF ESTIMATE = 0.26

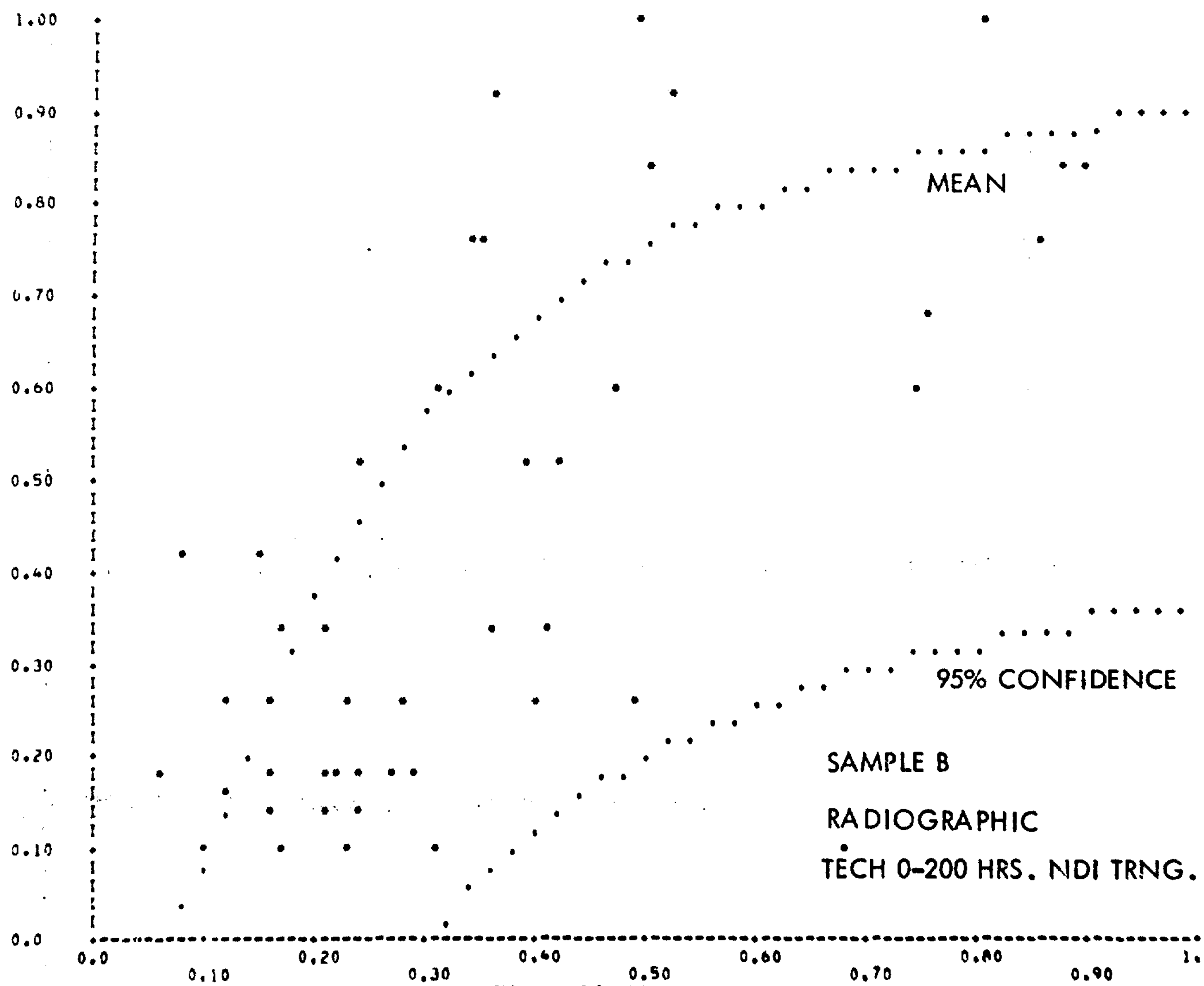


Figure 11-40

SAMPLE: C

METHOD: PT

NO OF INSPECTORS: 63

NO OF FLAWS: 41

INPUT RECORD: 01 C PT 1 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).

ALL TECH. SAMPLE C (PT)

EQUATION Y=A*X**B A = 0.142532D-01 B = 2.054904

COEFFICIENT OF CORRELATION = 0.947 COEFFICIENT OF DETERMINATION = 0.715

STANDARD ERROR OF ESTIMATE = 0.17

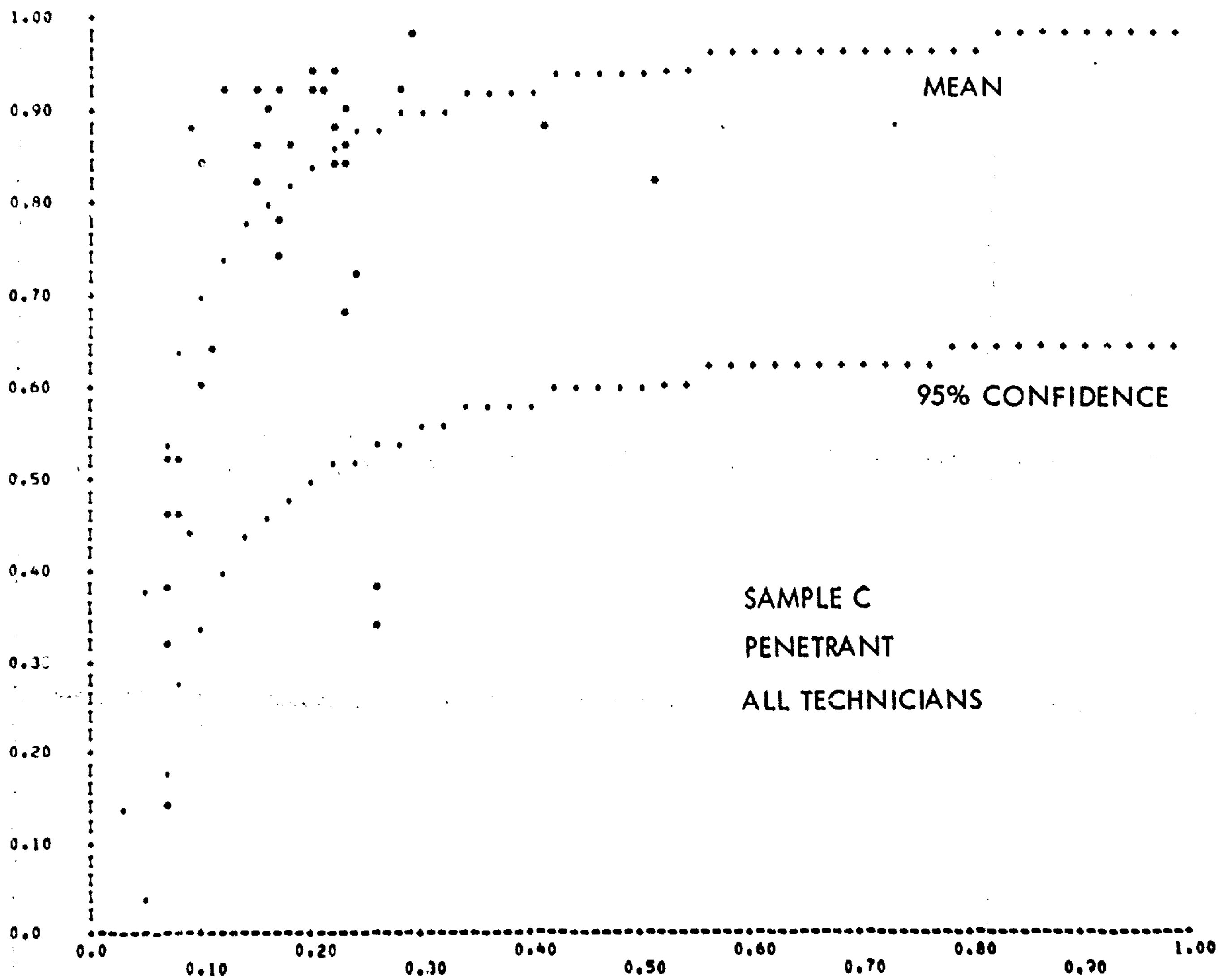


Figure 11-41

SAMPLE: C

METHOD: PT

NO OF INSPECTORS: 30

NO OF FLAWS: 41

INPUT RECORD: 02 C PT 1 77 99 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).

UPPER 50% ALL TECH SAMPLE C (PT)

EQUATION Y=A*X**B A = 0.1048590-05 B = 4.668105

COEFFICIENT OF CORRELATION - 0.915 COEFFICIENT OF DETERMINATION - 0.452

STANDARD ERROR OF ESTIMATE - 0.19

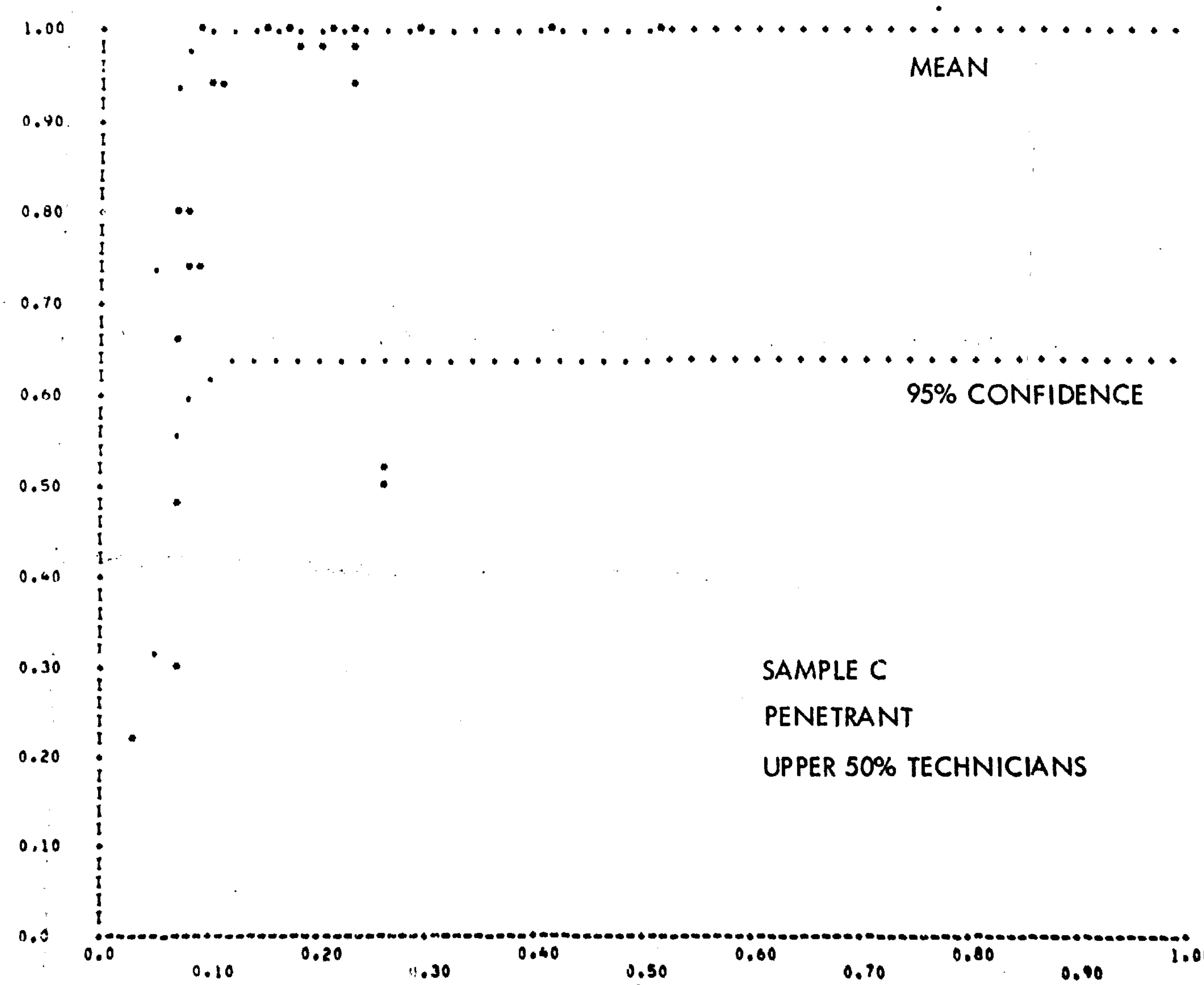


Figure 11-42

SAMPLE: C

METHOD: PT

NO OF INSPECTORS: 35

NO OF FLAWS: 41

INPUT RECORD: 03 C PT 1 0 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).

DEPOT TECH SAMPLE C (PT)

EQUATION Y=A*X**B A = 0.2735510-02 B = 2.556170

COEFFICIENT OF CORRELATION = 0.945 COEFFICIENT OF DETERMINATION = 0.439

STANDARD ERROR OF ESTIMATE = 0.19

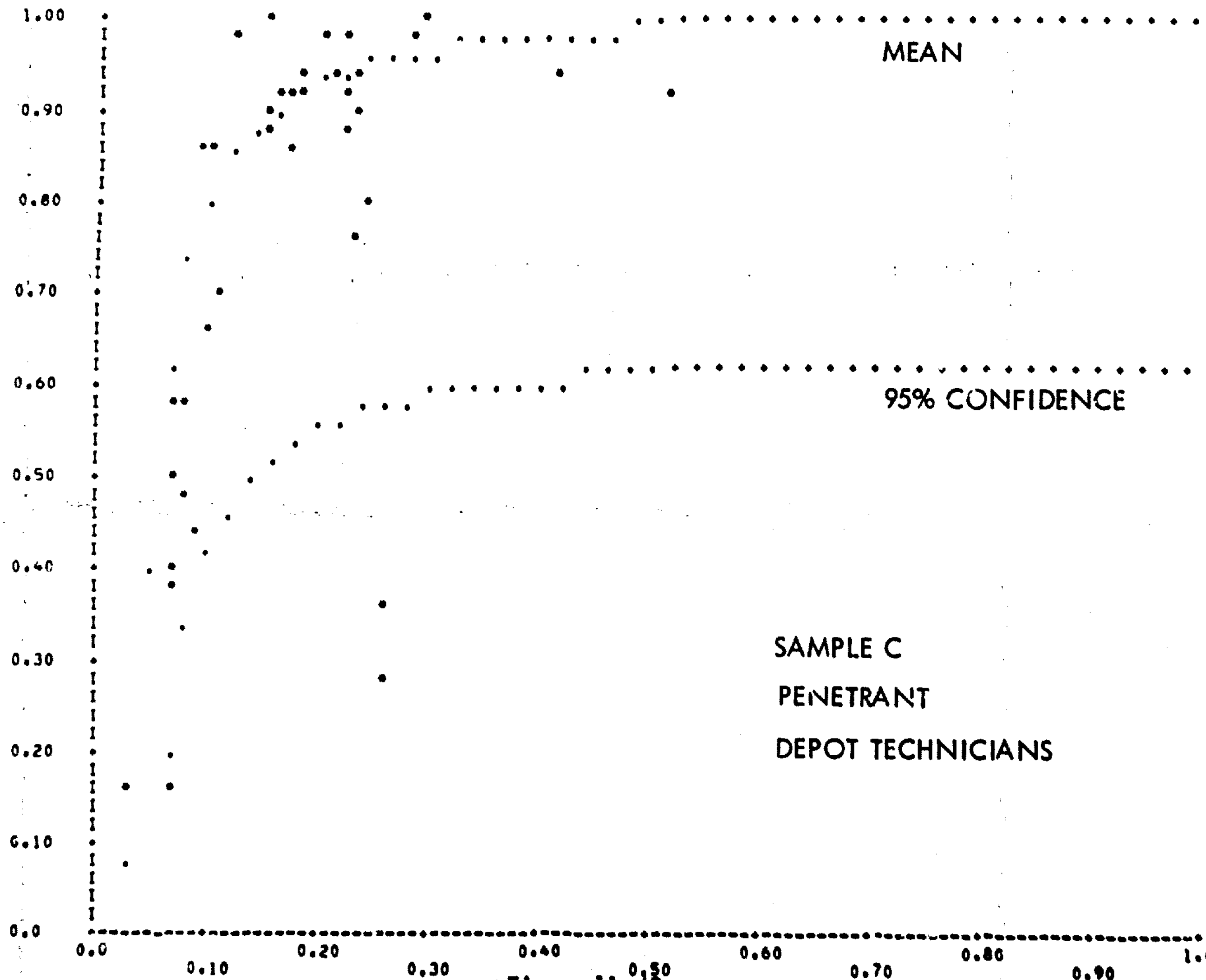


Figure 11-43

SAMPLE: C

METHOD: PT

NO OF INSPECTORS: 3

NO OF FLAWS: 41

INPUT RECORD: 05 C PT 1 3 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).

TECH SKILL LEVEL 3 SAMPLE C (PT)

EQUATION Y=A*X**B A = 0.5360890-04 B = 3.331322

COEFFICIENT OF CORRELATION = 0.876 COEFFICIENT OF DETERMINATION = 0.194

STANDARD ERROR OF ESTIMATE = 0.32

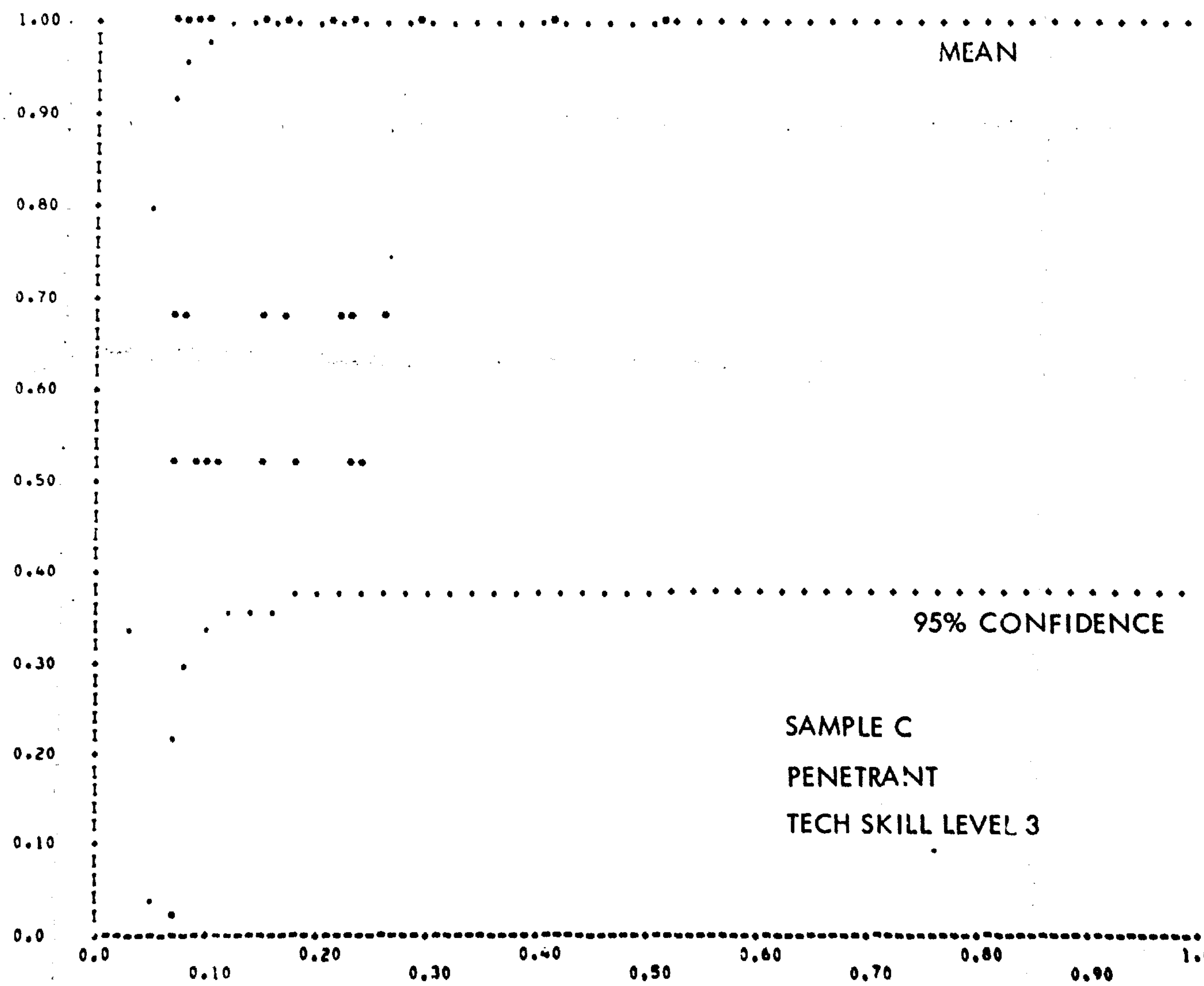


Figure 11-44

SAMPLE: C

METHOD: PT

NO OF INSPECTORS: 49

NO OF FLAWS: 41

INPUT RECORD: 05 C PT 1 5 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).

TECH SKILL LEVEL 5 SAMPLE C (PT)

EQUATION Y=A*X**B A = 0.1637870-01 B = 2.001279

COEFFICIENT OF CORRELATION = 0.947 COEFFICIENT OF DETERMINATION = 0.709

STANDARD ERROR OF ESTIMATE = 0.18

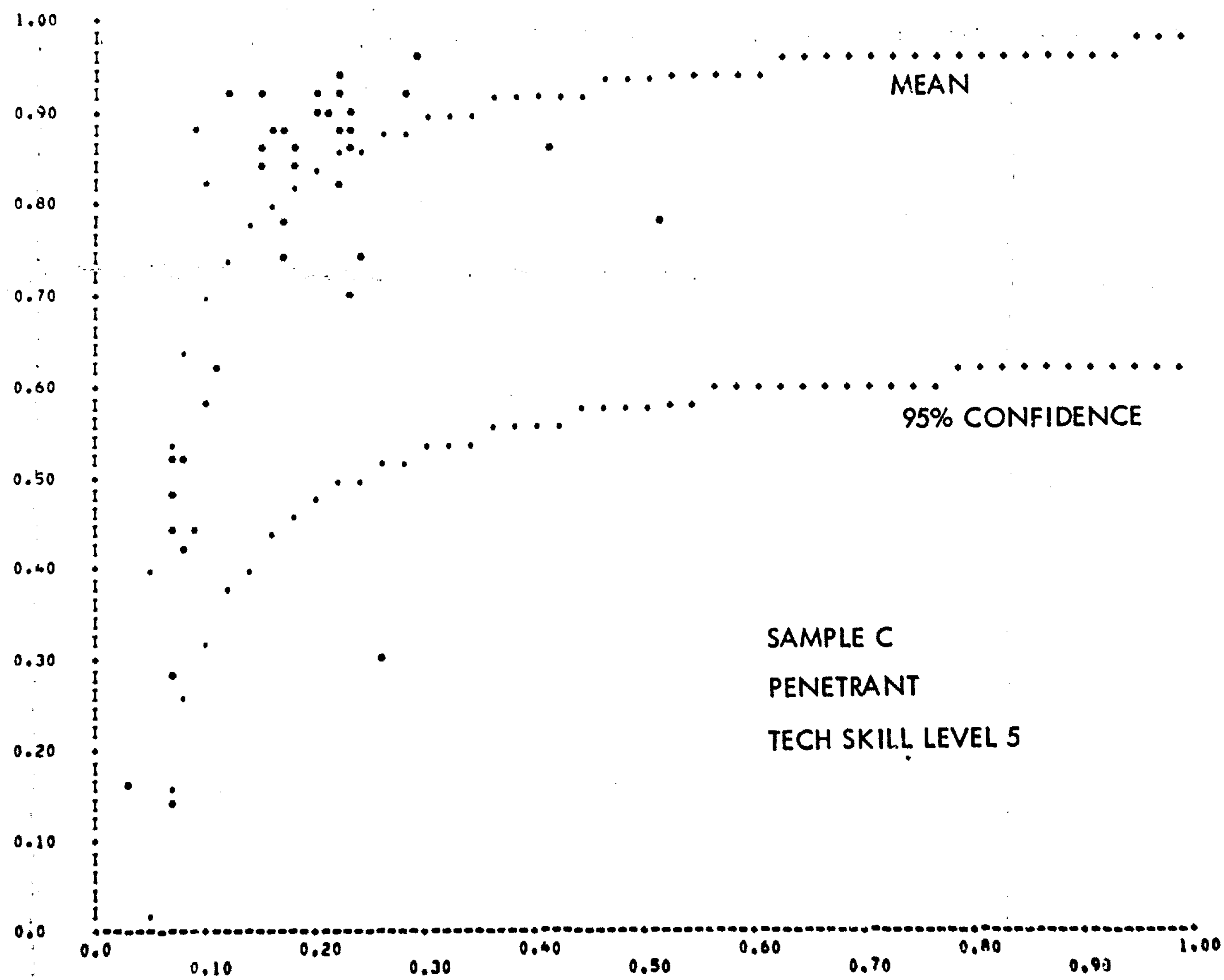


Figure 11-45

SAMPLE: C

METHOD: PT

NO OF INSPECTORS: 12

NO OF FLAWS: 41

INPUT RECORD: 05 C PT 1 7 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).

TECH SKILL LEVEL 7 SAMPLE C (PT)

EQUATION Y=A*X**B A = 0.480545D-03 B = 3.215131

COEFFICIENT OF CORRELATION = 0.948 COEFFICIENT OF DETERMINATION = 0.321

STANDARD ERROR OF ESTIMATE = 0.22

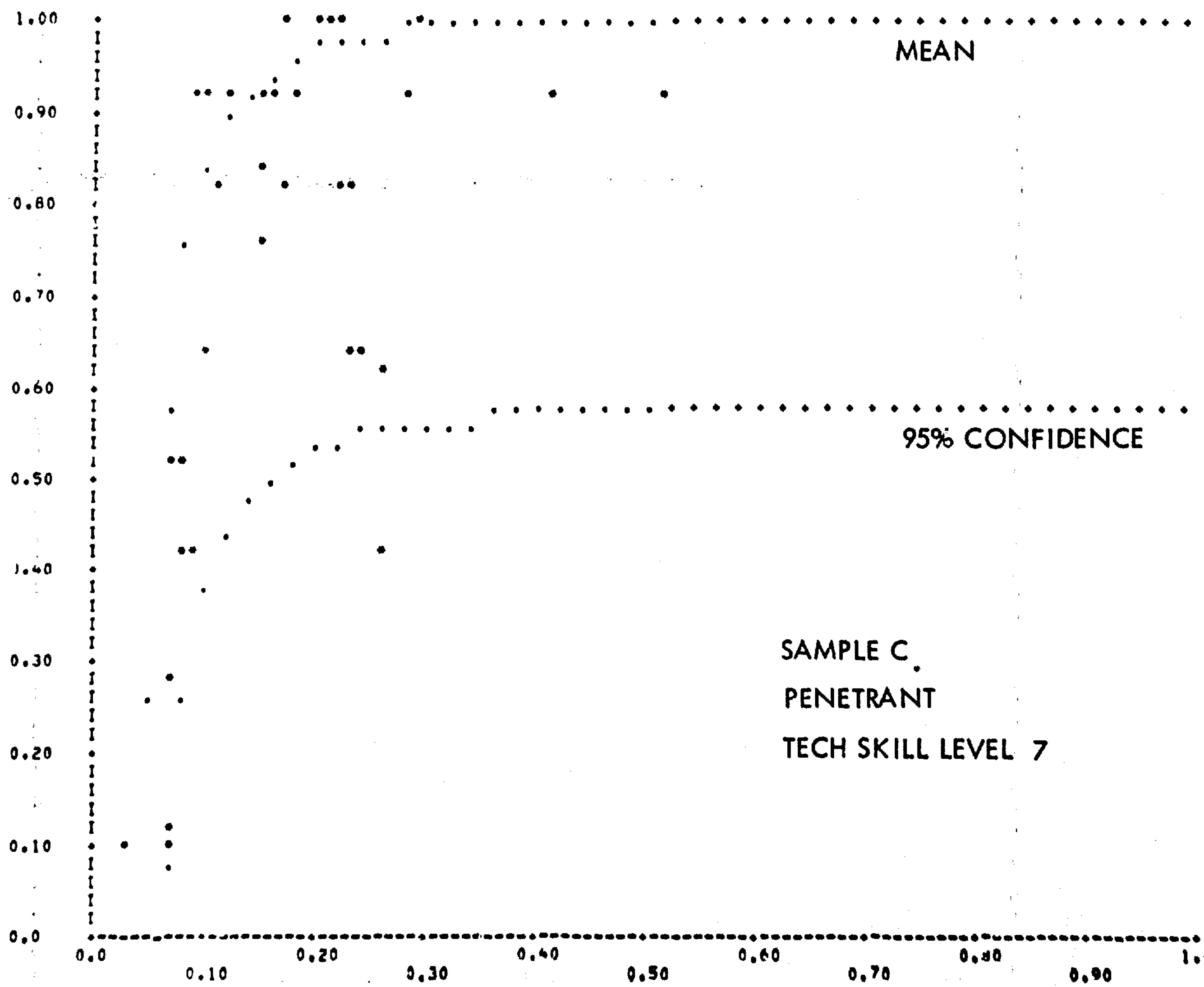


Figure 11-46

SAMPLE: C
METHOD: PT
NO OF INSPECTORS: 5
NO OF FLAWS: 41
INPUT RECORD: 07 C PT 1 N 95 10
CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).
TECH DID NOT GRAD, HS SAMPLE C (PT)

EQUATION Y=A*X**B A = 0.807036D-04 B = 4.209194

COEFFICIENT OF CORRELATION = 0.934 COEFFICIENT OF DETERMINATION = 0.360

STANDARD ERROR OF ESTIMATE = 0.32

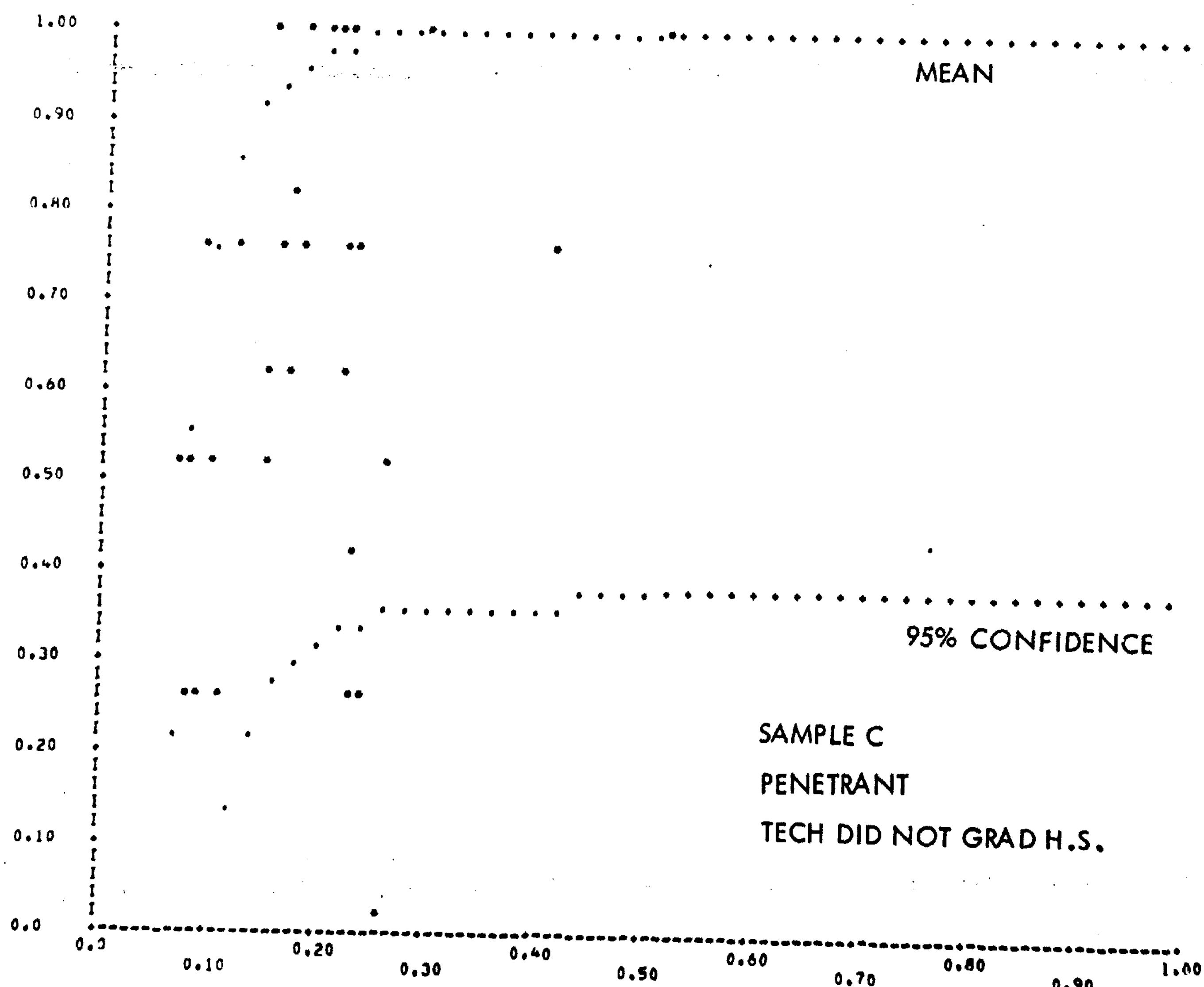


Figure 11-47

SAMPLE: C

METHOD: PT

NO OF INSPECTORS: 15

NO OF FLAWS: 41

INPUT RECORD: 08 C PT 1 151 250 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).

TECH UNDER 25YRS AGE SAMPLE C (PT)

EQUATION Y=A*X**B A = 0.5692310-01 B = 1.508703

COEFFICIENT OF CORRELATION = 0.854 COEFFICIENT OF DETERMINATION = 0.259

STANDARD ERROR OF ESTIMATE = 0.24

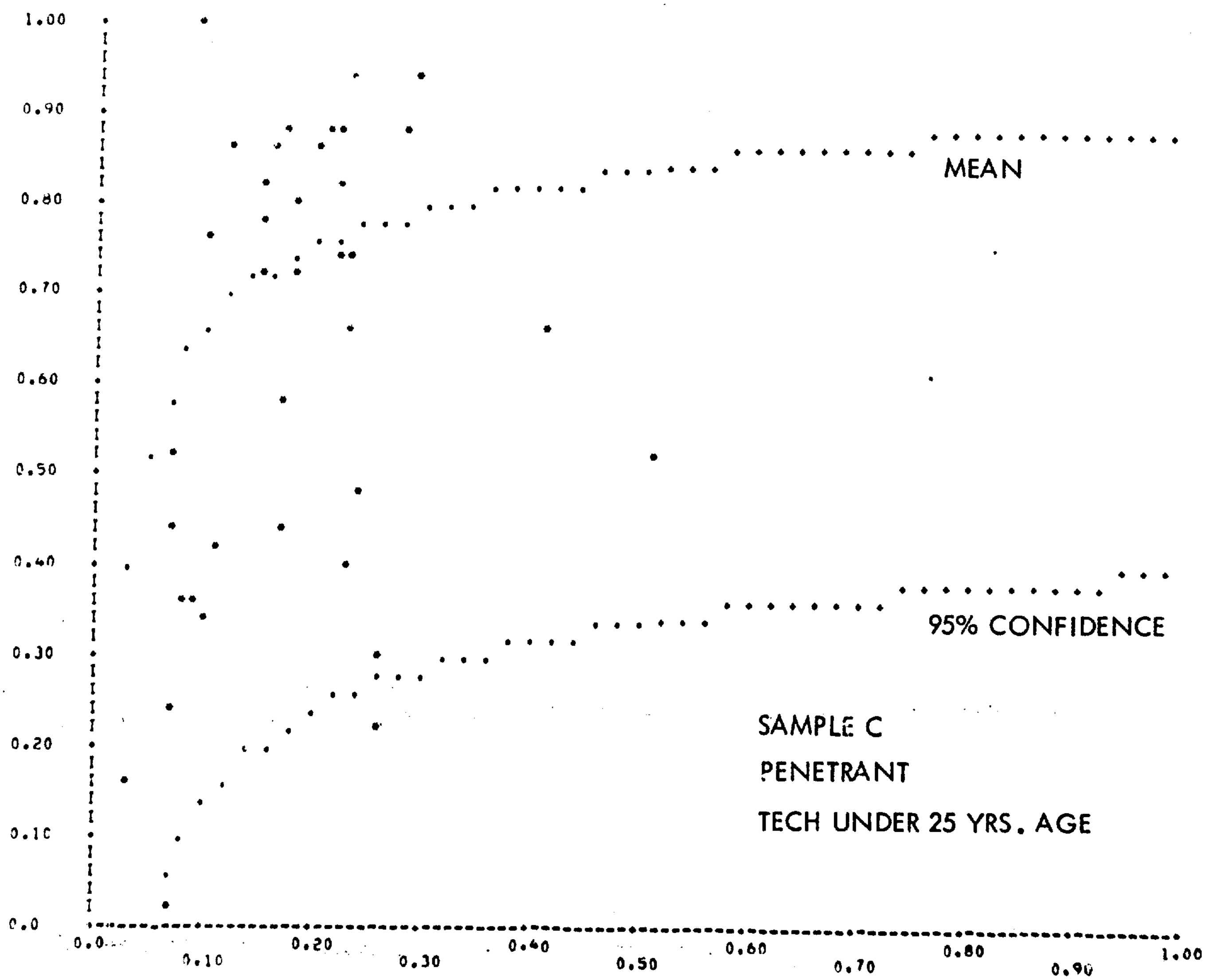


Figure 11-48

SAMPLE: C

METHOD: PT

NO OF INSPECTORS: 18

NO OF FLAWS: 41

INPUT RECORD: 08 C PT 1 400 990 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).

TECH OVER 40YRS AGE SAMPLE C (PT)

EQUATION Y=A*X**B A = 0.4165660-02 B = 2.528848

COEFFICIENT OF CORRELATION = 0.948 COEFFICIENT OF DETERMINATION = 0.443

STANDARD ERROR OF ESTIMATE = 0.18

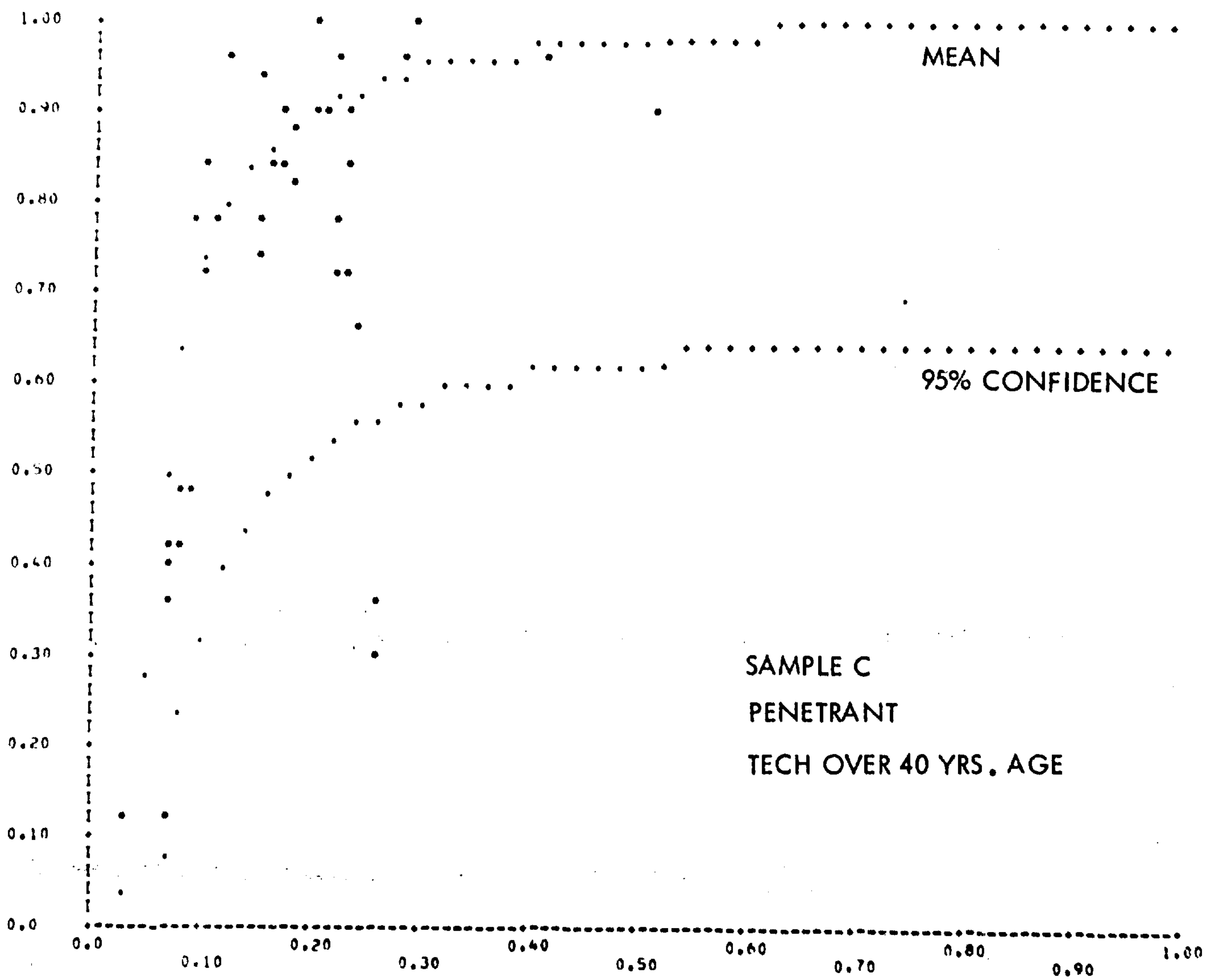


Figure 11-49

SAMPLE: C

METHOD: PT

NO OF INSPECTORS: 53

NO OF FLAWS: 41

INPUT RECORD: 09 C PT 1 011 099 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).

TECH OVER 10 YRS EXPER. SAMPLE C (PT)

EQUATION Y=A*X**B A = 0.1647270-01 B = 2.007067

COEFFICIENT OF CORRELATION = 0.951 COEFFICIENT OF DETERMINATION = 0.716

STANDARD ERROR OF ESTIMATE = 0.17

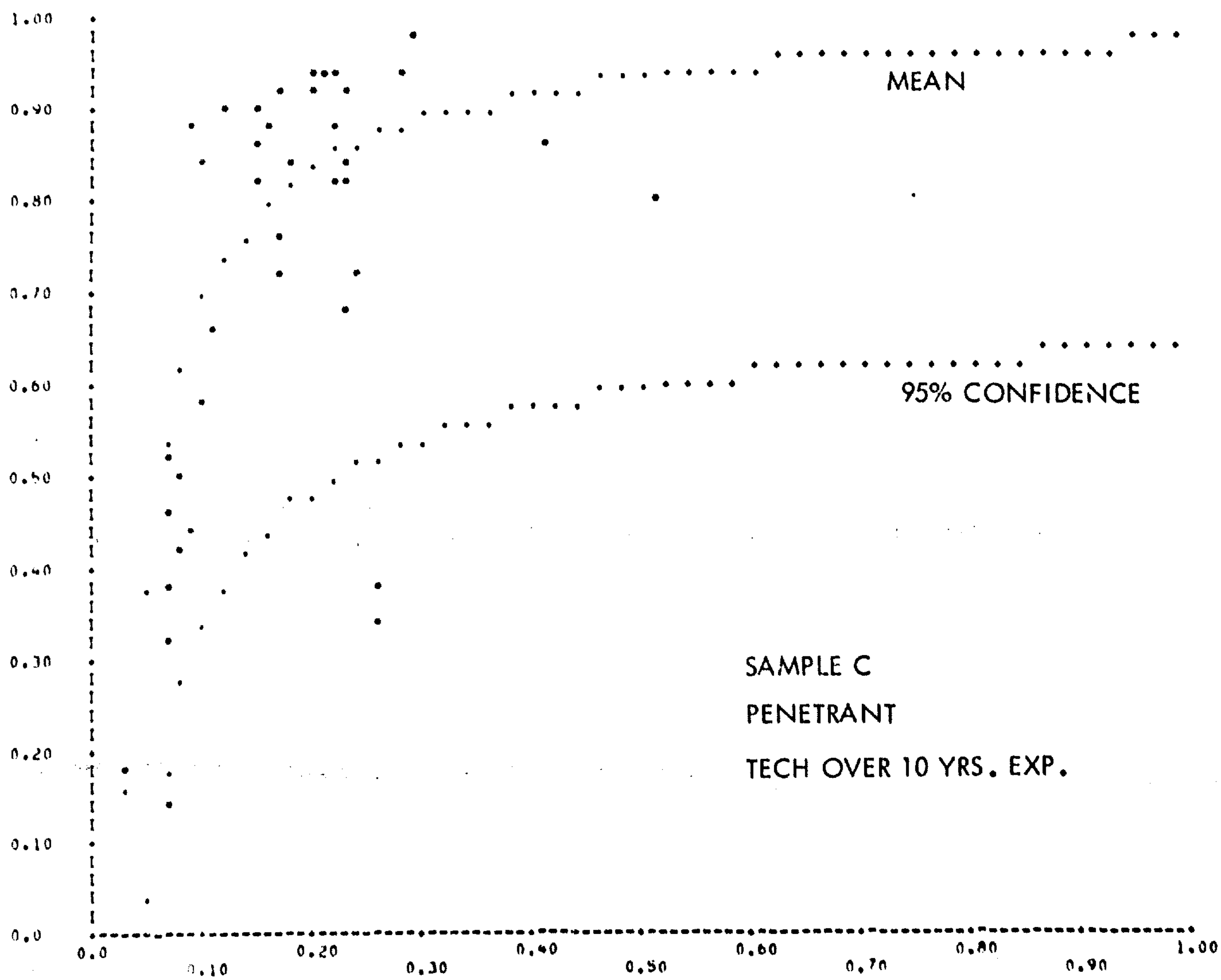


Figure 11-50

SAMPLE: C

METHOD: PT

NO OF INSPECTORS: 28

NO OF FLAWS: 41

INPUT RECORD: 10 C PT 1 000 200 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).

TECH 0-200HRS NDI TRNG SAMPLE C (PT)

EQUATION Y=A*X**B A = 0.2963060D-03 B = 3.311321

COEFFICIENT OF CORRELATION = 0.942 COEFFICIENT OF DETERMINATION = 0.351

STANDARD ERROR OF ESTIMATE = 0.22

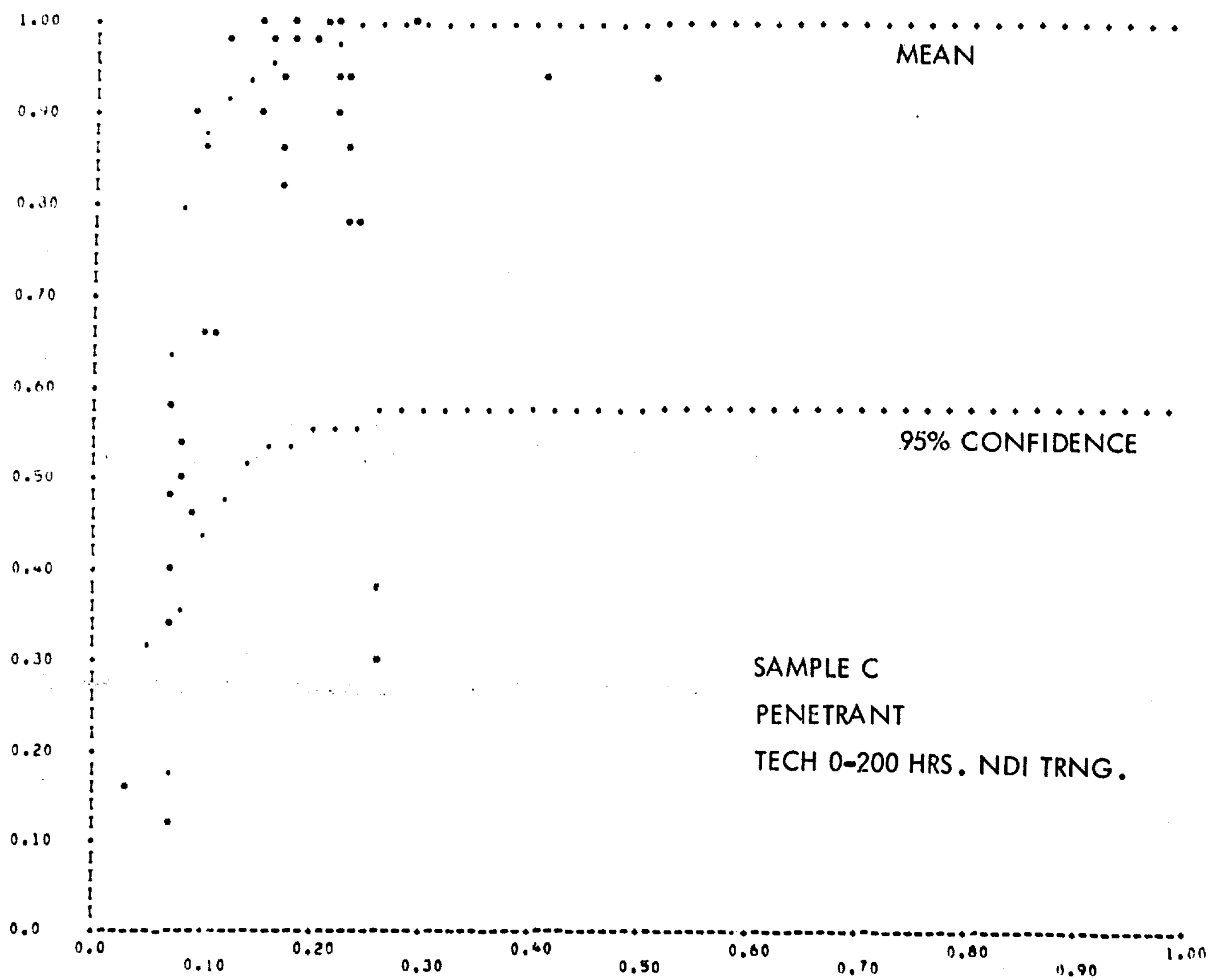


Figure 11-51

SAMPLE: C

METHOD: PT

NO OF INSPECTORS: 9

NO OF FLAWS: 41

INPUT RECORD: 10 C PT 1 500 999 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).

TECH 500+ HRS NDI TRNG SAMPLE C (PT)

EQUATION Y=A*X**B A = 0.3467350-04 B = 3.722731

COEFFICIENT OF CORRELATION = 0.852 COEFFICIENT OF DETERMINATION = 0.273

STANDARD ERROR OF ESTIMATE = 0.26

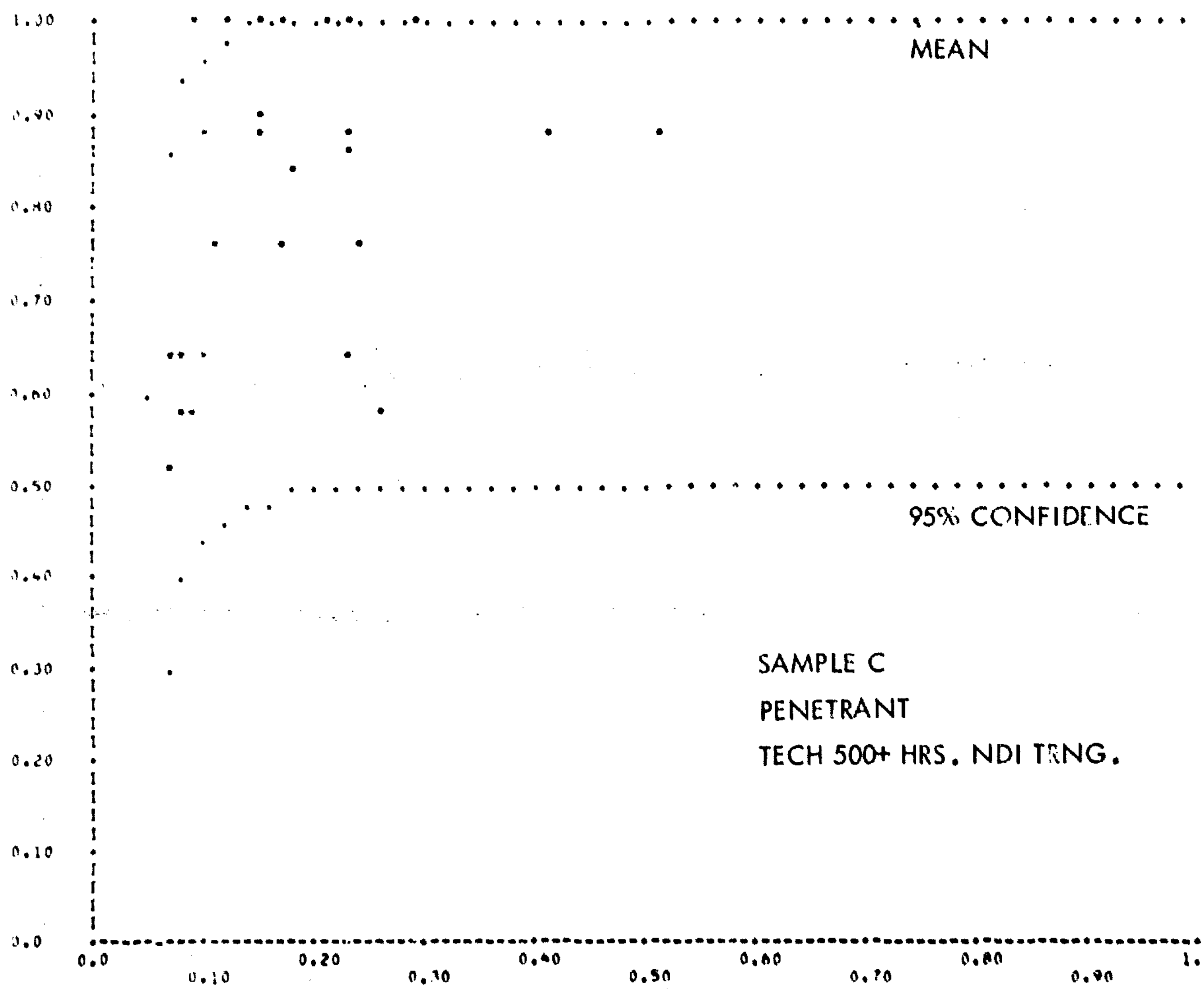


Figure 11-52

SAMPLE: C

METHOD: UT

NO OF INSPECTORS: 32

NO OF FLAWS: 41

INPUT RECORD: 01 C UT 1 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).

ALL TECH, SAMPLE C (UT)

EQUATION Y=A*X**B A = 0.103177 B = 1.162271

COEFFICIENT OF CORRELATION = 0.718 COEFFICIENT OF DETERMINATION = 0.717

STANDARD ERROR OF ESTIMATE = 0.11

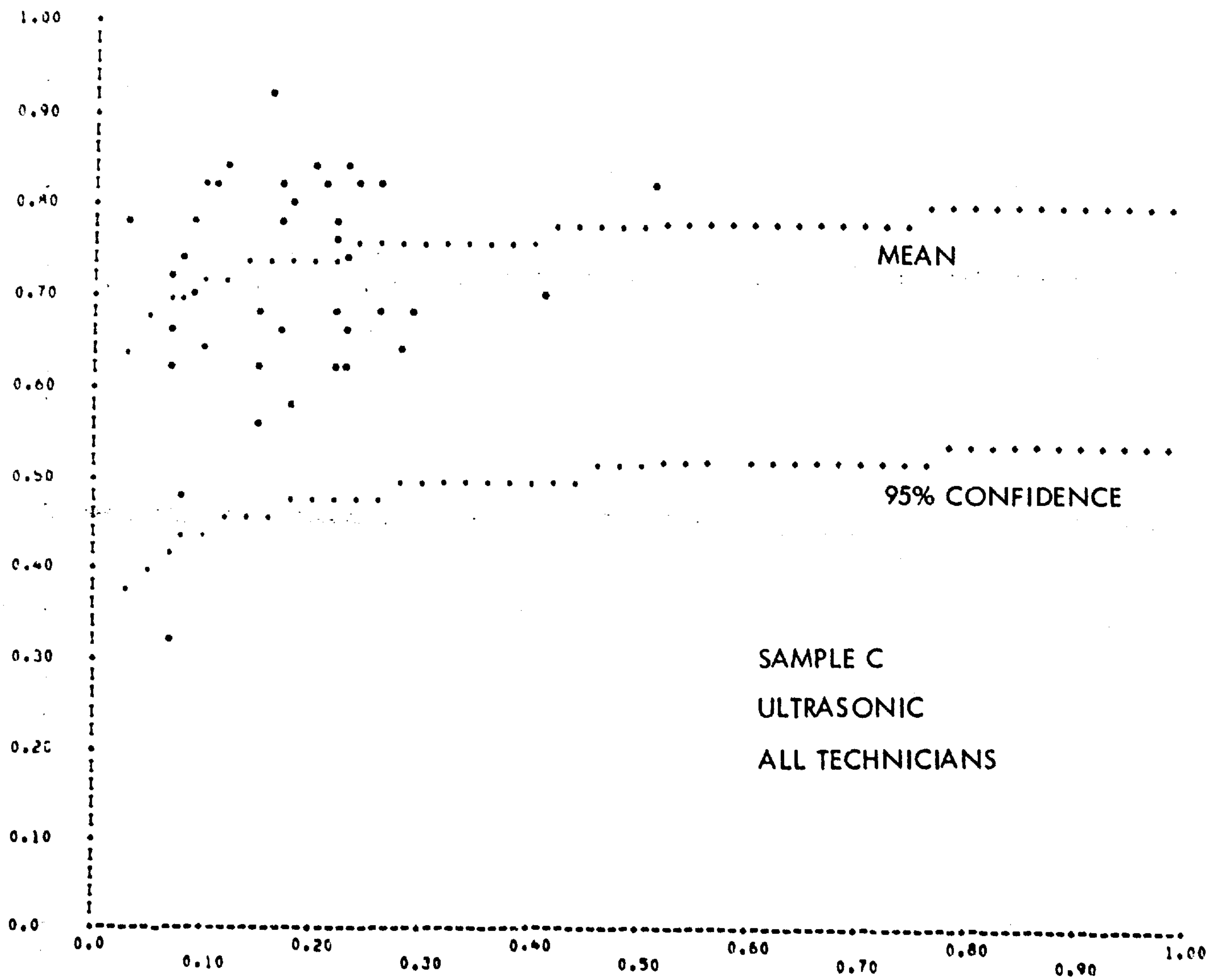


Figure 11-53

SAMPLE: C

METHOD: UT

NO OF INSPECTORS: 18

NO OF FLAWS: 41

INPUT RECORD: 02 C UT 1 82 99 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).

UPPER 50% ALL TECH SAMPLE C (UT)

EQUATION Y=A*X**B A = 0.168337D-04 B = 3.718621

COEFFICIENT OF CORRELATION = 0.429 COEFFICIENT OF DETERMINATION = 0.359

STANDARD ERROR OF ESTIMATE = 0.17

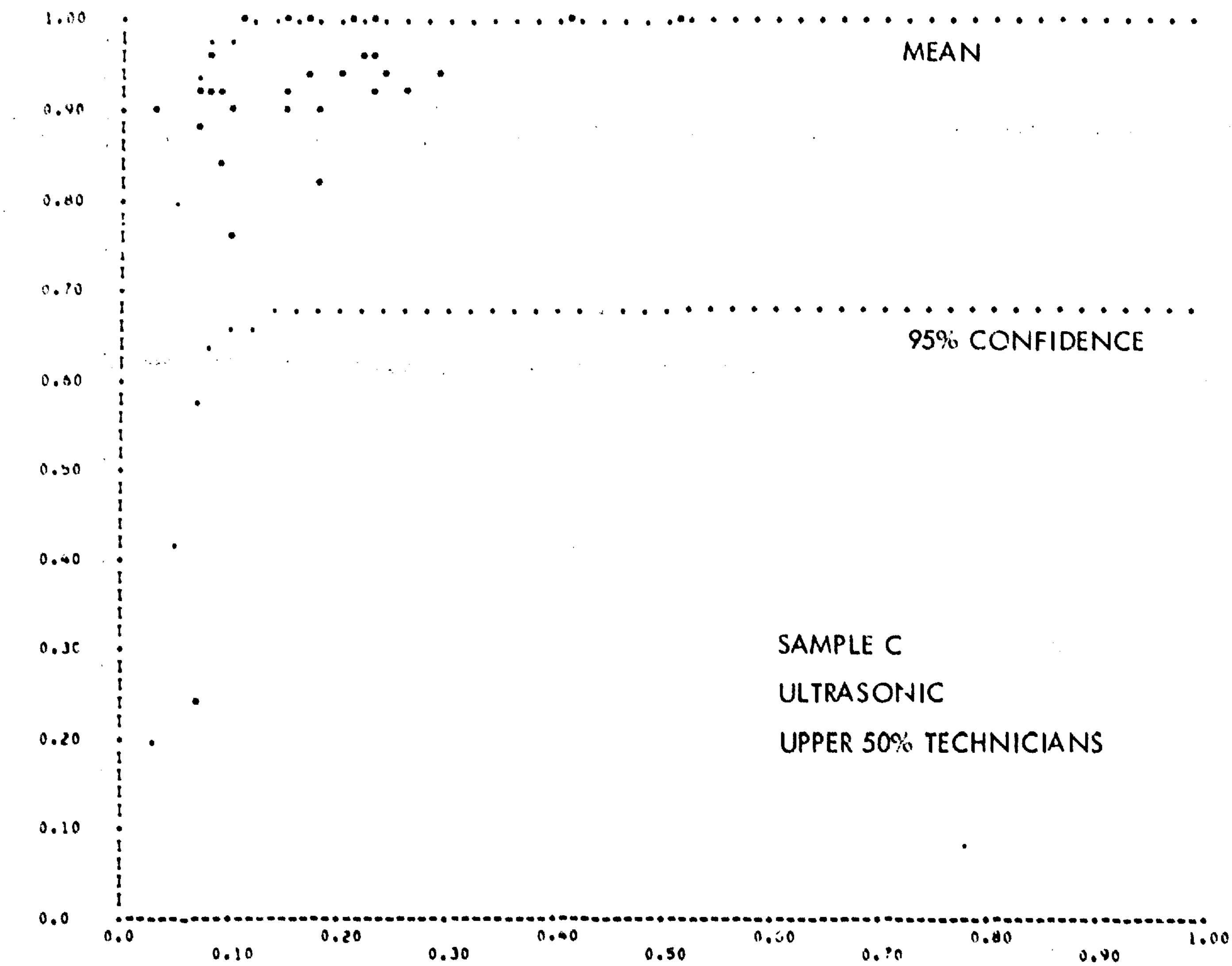


Figure 11-54

SAMPLE: C

METHOD: UT

NO OF INSPECTORS: 10

NO OF FLAWS: 41

INPUT RECORD: 03 C UT 1 D 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).

DEPOT TECH SAMPLE C (UT)

EQUATION Y=A*X**B A = 0.8412690-01 B = 1.029217

COEFFICIENT OF CORRELATION = 0.505 COEFFICIENT OF DETERMINATION = 0.105

STANDARD ERROR OF ESTIMATE = 0.18

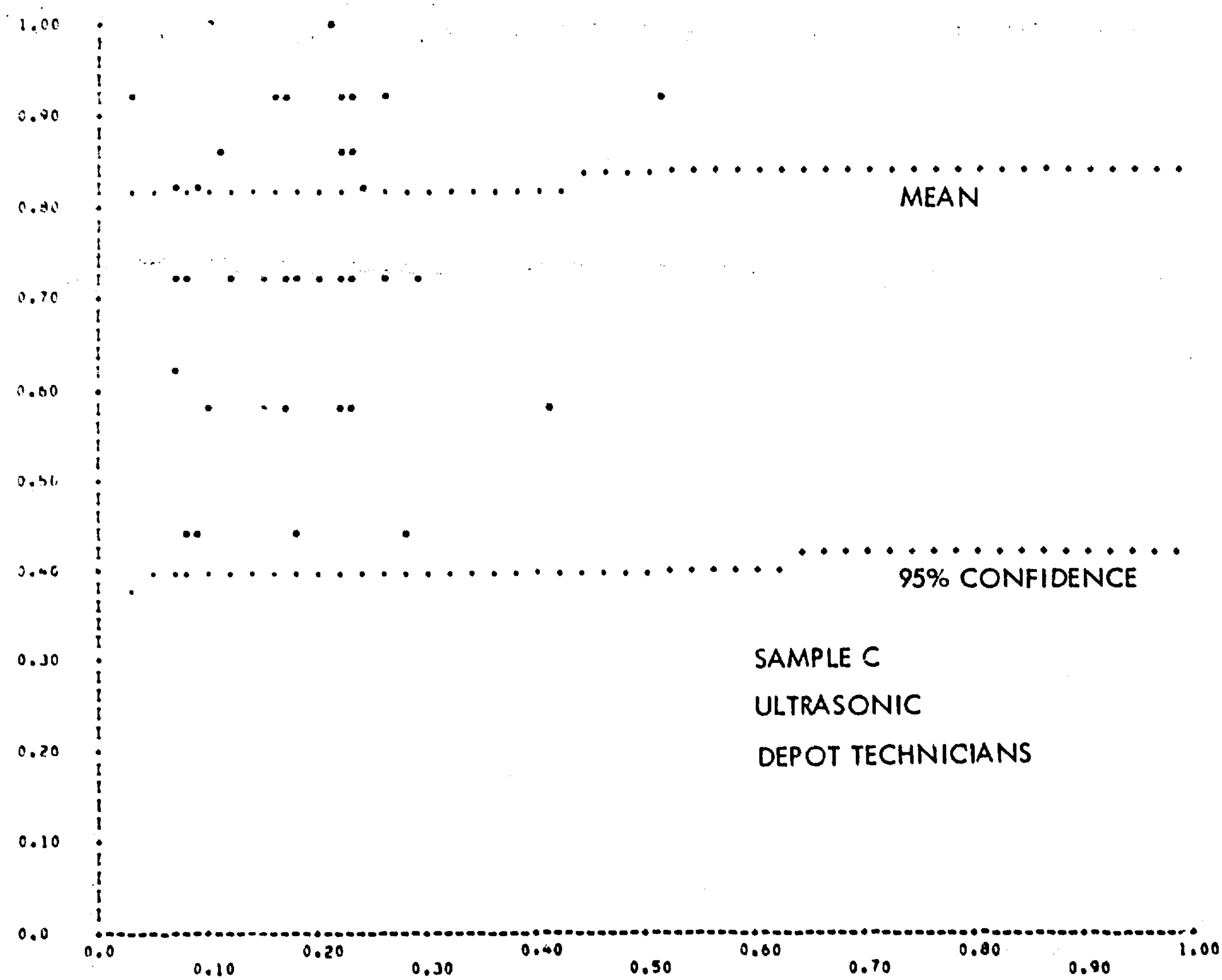


Figure 11-55

SAMPLE: C

METHOD: UT

NO OF INSPECTORS: 26

NO OF FLAWS: 41

INPUT RECORD: 05 C UT 1 5 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).

TECH SKILL LEVEL 5 SAMPLE C (UT)

EQUATION Y=A*X**B A = 0.141933 B = 1.030521

COEFFICIENT OF CORRELATION = 0.730 COEFFICIENT OF DETERMINATION = 0.683

STANDARD ERROR OF ESTIMATE = 0.11

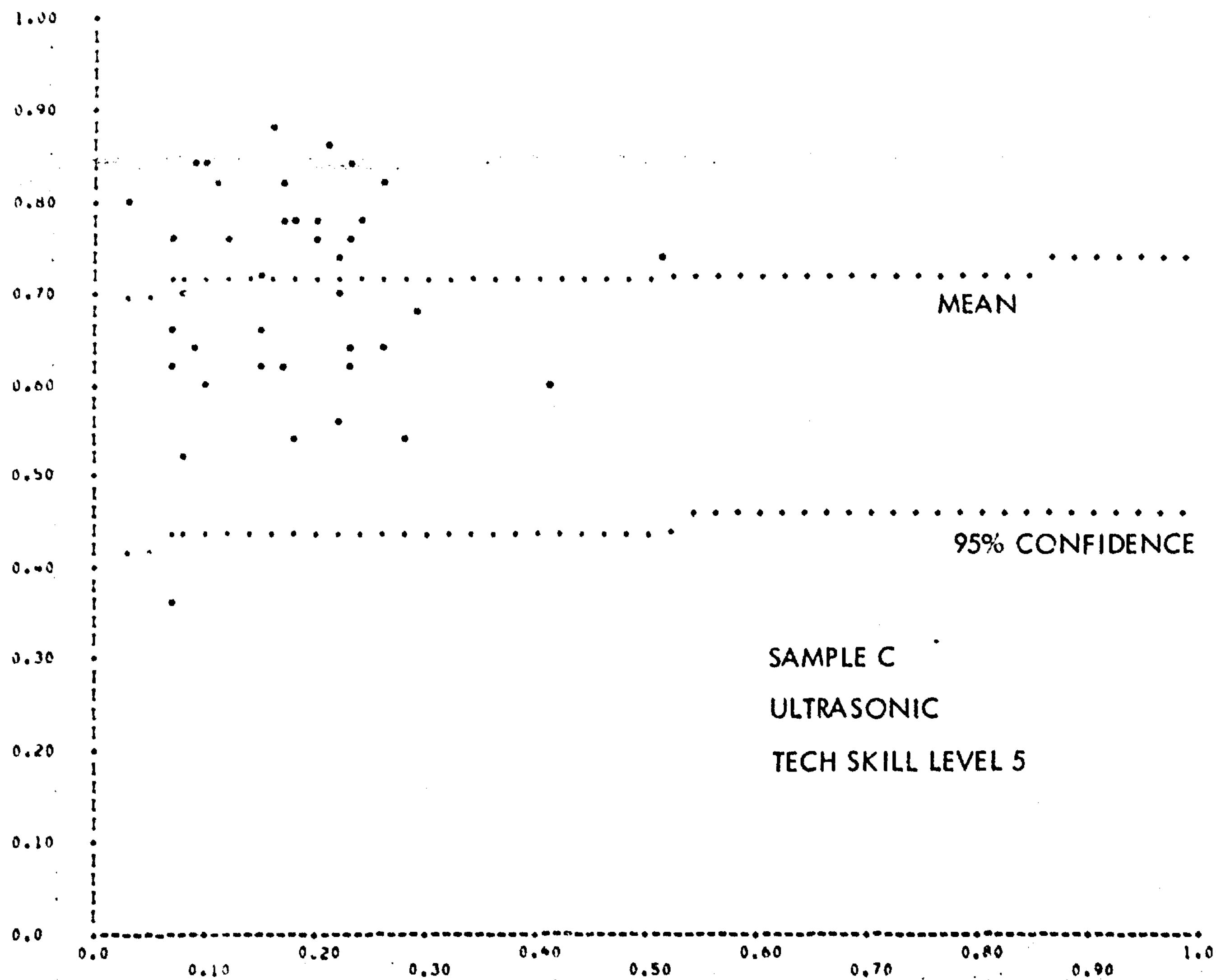


Figure 11-56

SAMPLE: C

METHOD: UT

NO OF INSPECTORS: 7

NO OF FLAWS: 41

INPUT RECORD: 05 C UT 1 7 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).

TECH SKILL LEVEL 7 SAMPLE C (UT)

EQUATION Y=A*X**B A = 0.1295290-03 B = 3.124393

COEFFICIENT OF CORRELATION = 0.429 COEFFICIENT OF DETERMINATION = 0.207

STANDARD ERROR OF ESTIMATE = 0.28

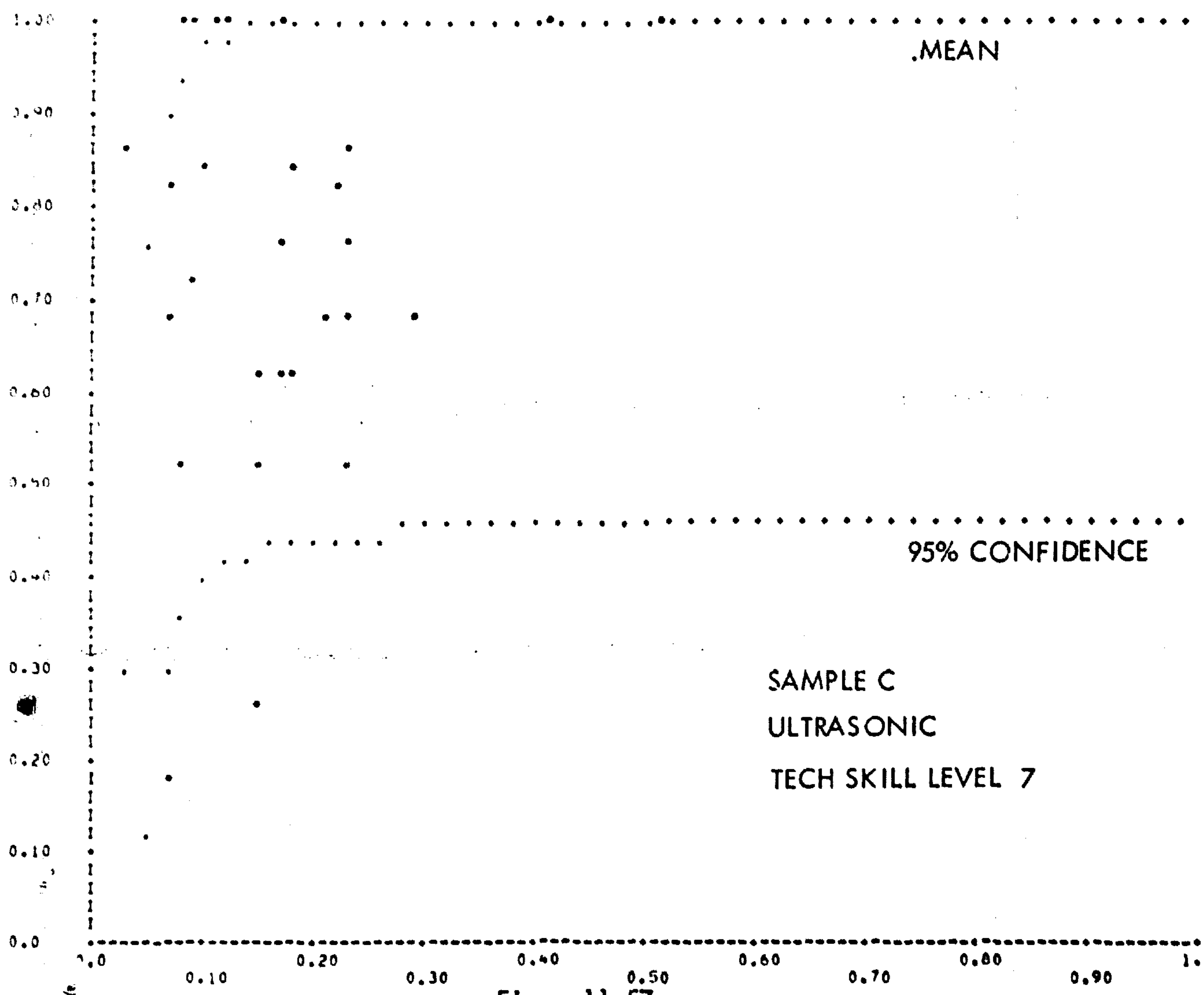


Figure 11-57

SAMPLE: C
METHOD: UT
NO OF INSPECTORS: 10
NO OF FLAWS: 41
INPUT RECORD: 08 C UT 1 150 250 95 10
CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).
TECH UNDER 25YRS AGE SAMPLE C (UT)

EQUATION Y=A*X**B A = 0.180866 B = 1.123296

COEFFICIENT OF CORRELATION = 0.848 COEFFICIENT OF DETERMINATION = 0.696

STANDARD ERROR OF ESTIMATE = 0.13

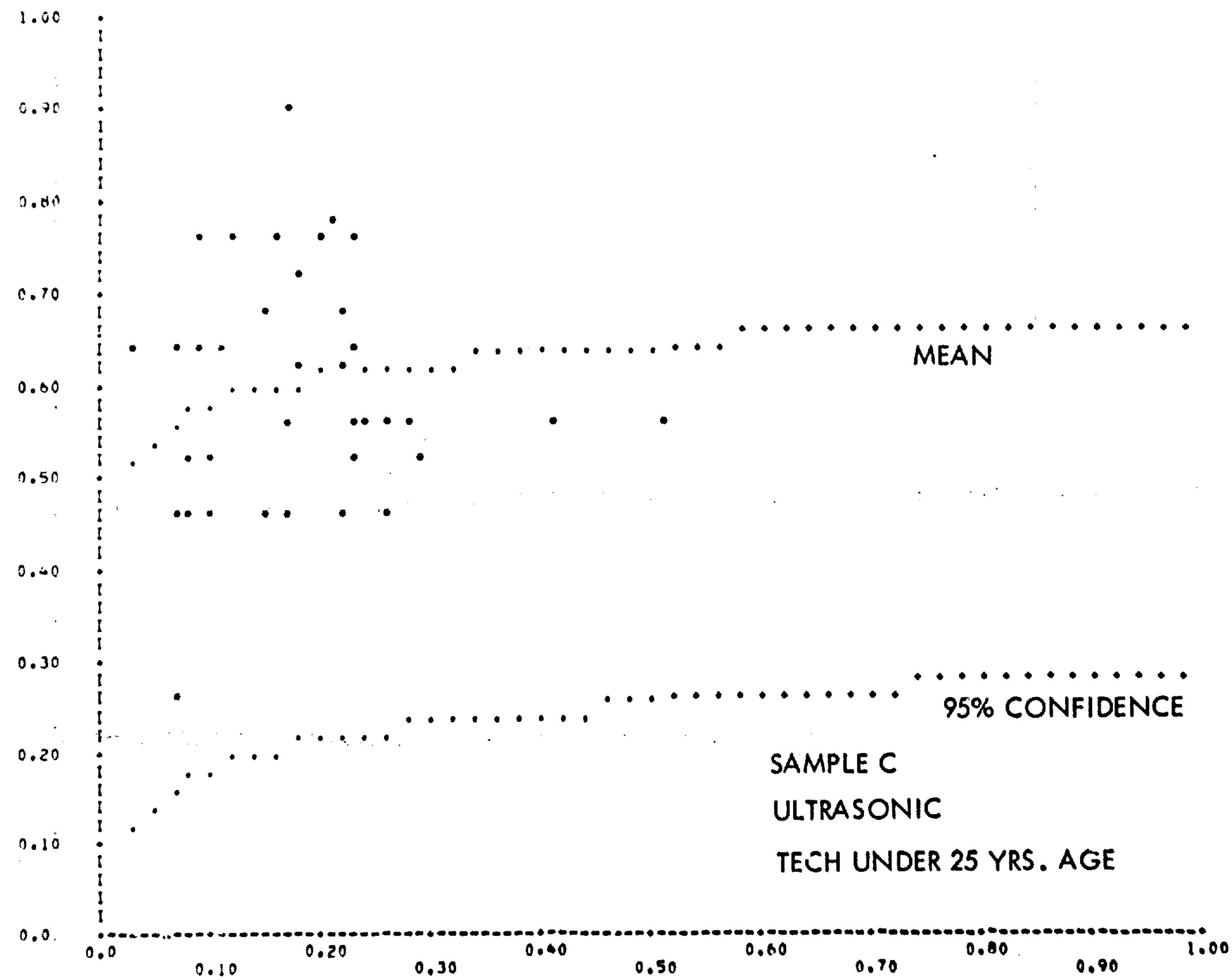


Figure 11-58

SAMPLE: C

METHOD: UT

NO OF INSPECTORS: 5

NO OF FLAWS: 41

INPUT RECORD: 08 C UT 1 400 990 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).

TECH OVER 40YRS AGE SAMPLE C (UT)

EQUATION Y=A*X**B A = 0.1831060-02 B = 2.266012

COEFFICIENT OF CORRELATION = 0.177 COEFFICIENT OF DETERMINATION = 0.109

STANDARD ERROR OF ESTIMATE = 0.40

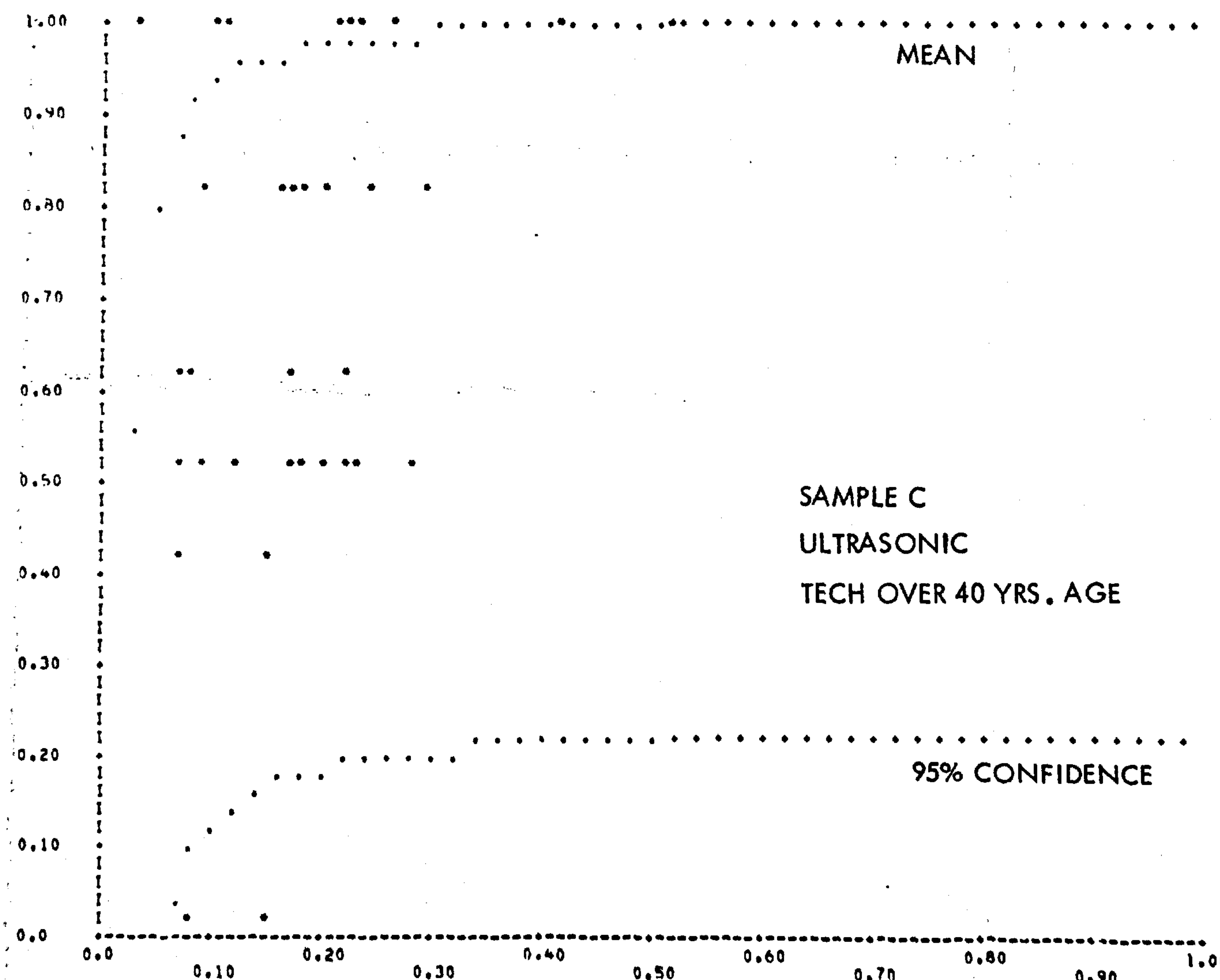


Figure 11-59

SAMPLE: C

METHOD: UT

NO OF INSPECTORS: 30

NO OF FLAWS: 41

INPUT RECORD: 09 C UT 1 011 099 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).

TECH OVER 10 YRS EXPER. SAMPLE C (UT)

EQUATION Y=A*X**B A = 0.120915 B = 1.056774

COEFFICIENT OF CORRELATION = 0.638 COEFFICIENT OF DETERMINATION = 0.658

STANDARD ERROR OF ESTIMATE = 0.11

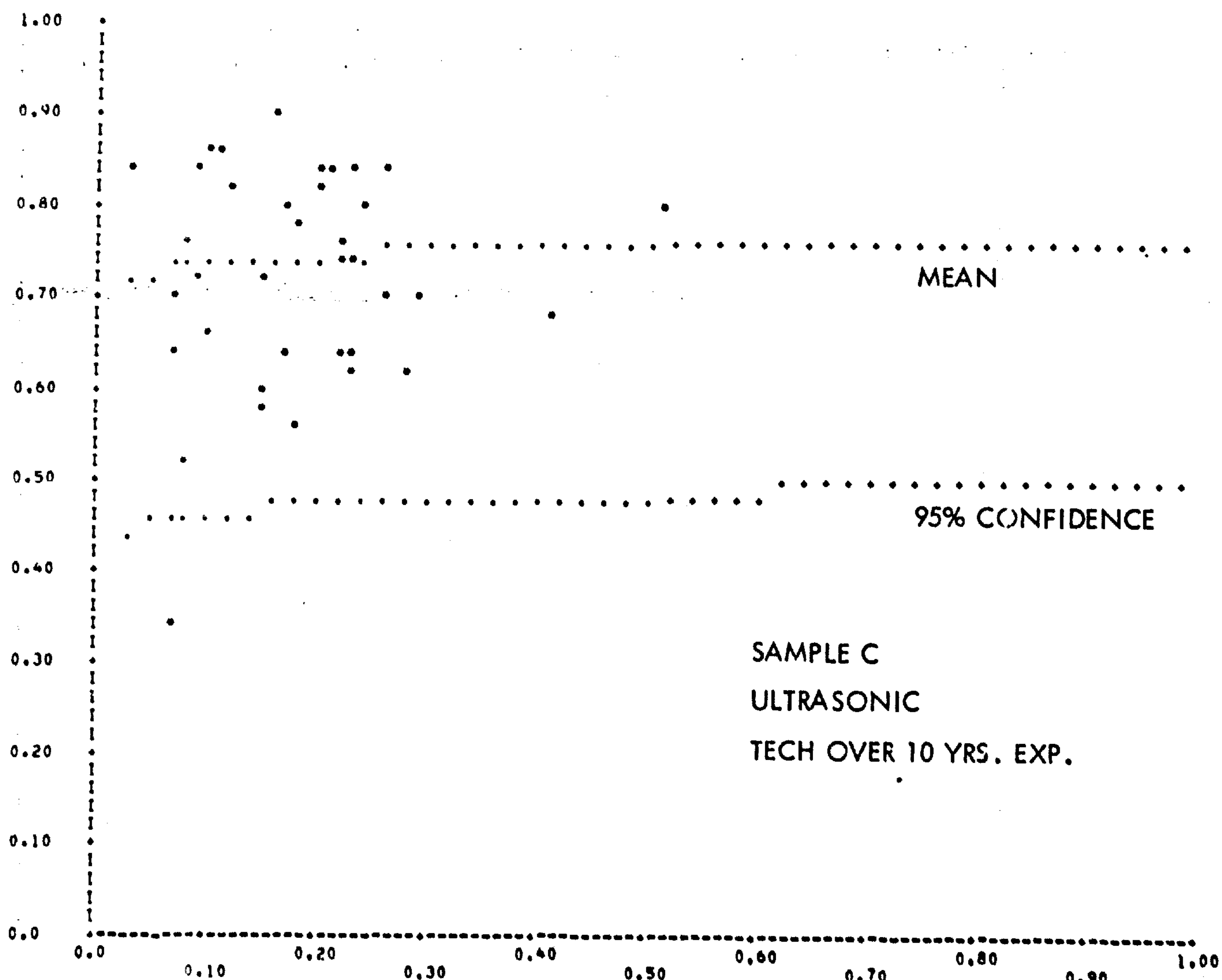


Figure 11-60

SAMPLE: C

METHOD: UT

NO OF INSPECTORS: 11

NO OF FLAWS: 41

INPUT RECORD: 10 C UT 1 000 200 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).

TECH 0-200HRS NDI TRNG SAMPLE C (UT)

EQUATION Y=A*X**B A = 0.221678 B = 0.832286

COEFFICIENT OF CORRELATION = 0.697 COEFFICIENT OF DETERMINATION = 0.398

STANDARD ERROR OF ESTIMATE = 0.15

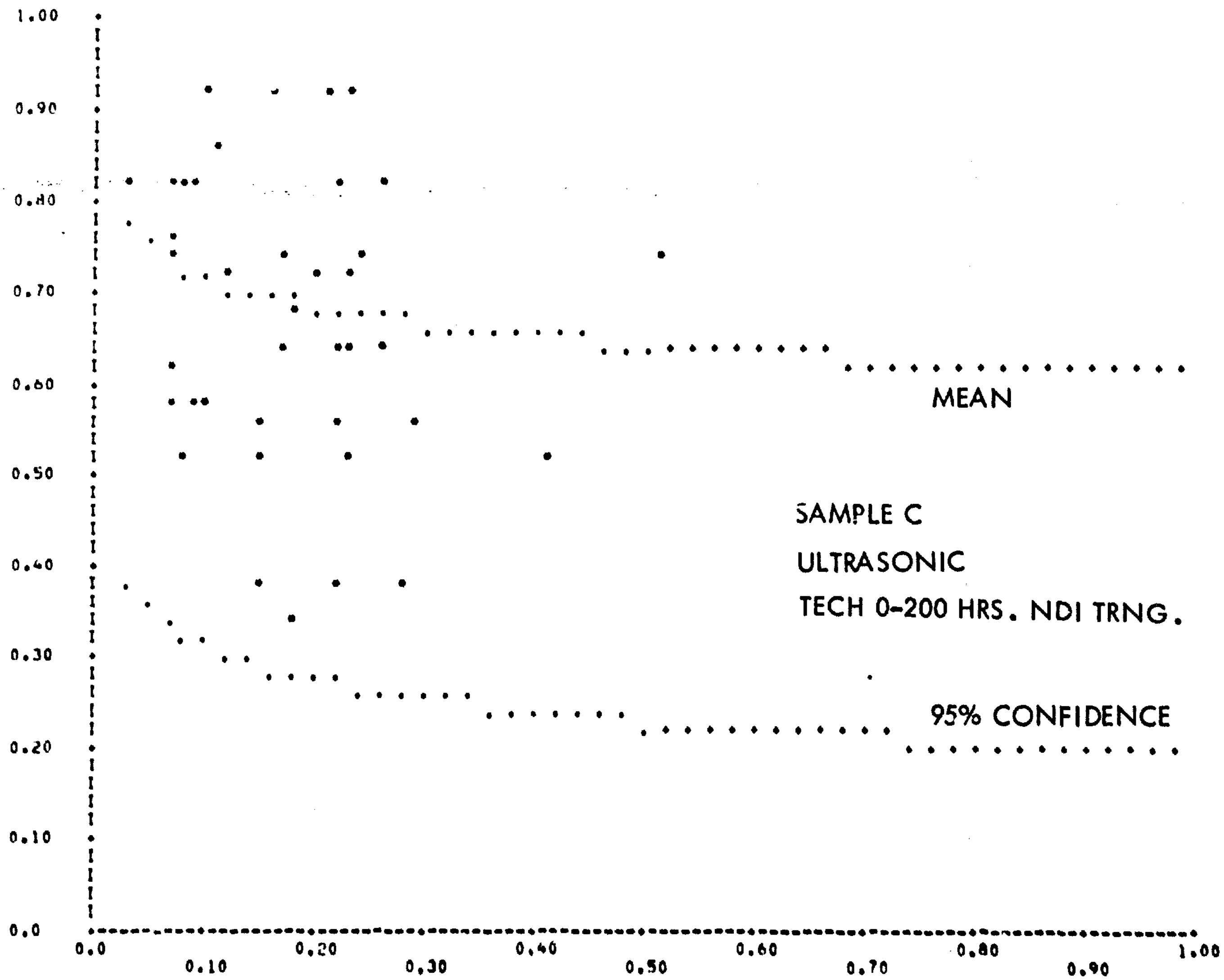


Figure 11-61

SAMPLE: C

METHOD: UT

NO OF INSPECTORS: 9

NO OF FLAWS: 41

INPUT RECORD: 10 C UT 1 500 999 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).

TECH 500+ HRS NDI TRNG SAMPLE C (UT)

EQUATION Y=A*X**B A = 0.292721D-04 B = 2.821667

COEFFICIENT OF CORRELATION = 0.601 COEFFICIENT OF DETERMINATION = 0.176

STANDARD ERROR OF ESTIMATE = 0.21

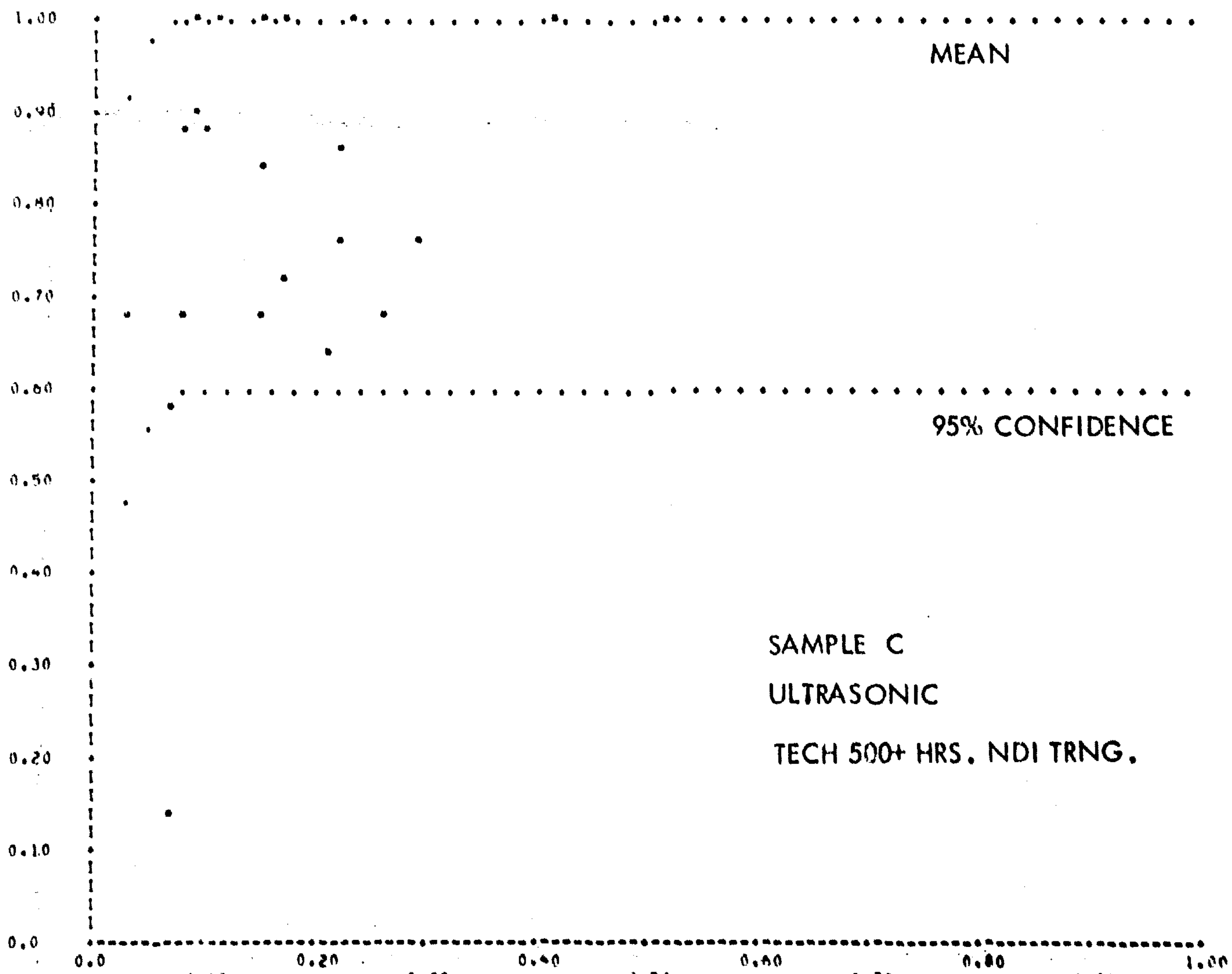


Figure 11-62

SAMPLE: E

METHOD: EH

NO OF INSPECTORS: 107

NO OF FLAWS: 6

INPUT RECORD: 01 E EH 2 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW BORE LENGTH (INCHES).

ALL TECH. SAMPLE E (EH)

EQUATION Y=A*X**B A = 0.216718 B = 1.272781

COEFFICIENT OF CORRELATION = 0.896 COEFFICIENT OF DETERMINATION = 0.696

STANDARD ERROR OF ESTIMATE = 0.13

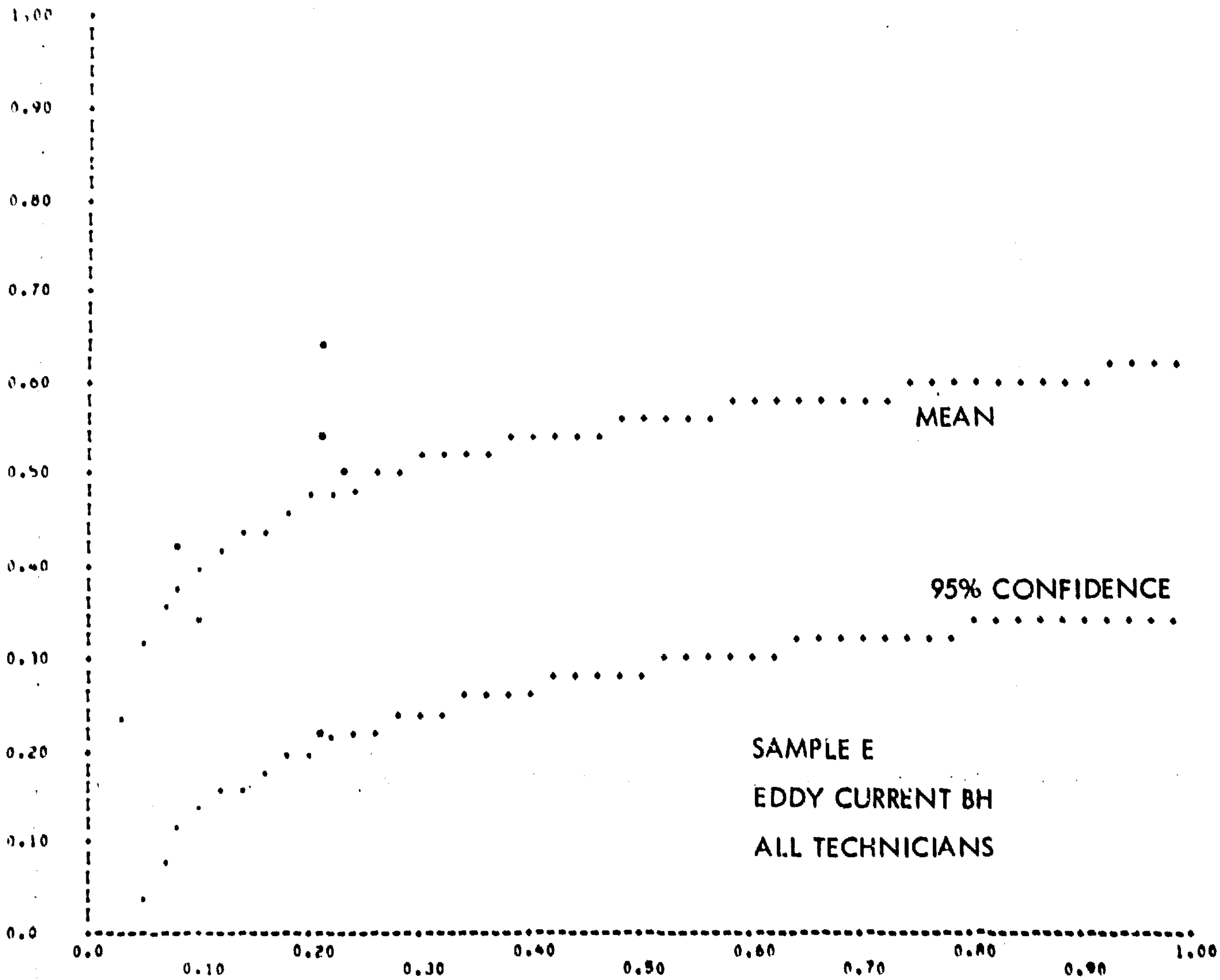


Figure 11-63

SAMPLE: E

METHOD: EH

NO OF INSPECTORS: 57

NO OF FLAWS: 6

INPUT RECORD: 03 E EH 2 0 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW BORE LENGTH (INCHES).

DEPOT TECH SAMPLE E (EH)

EQUATION Y=A*X**B A = 0.173834 B = 1.258267

COEFFICIENT OF CORRELATION = 0.807 COEFFICIENT OF DETERMINATION = 0.603

STANDARD ERROR OF ESTIMATE = 0.15

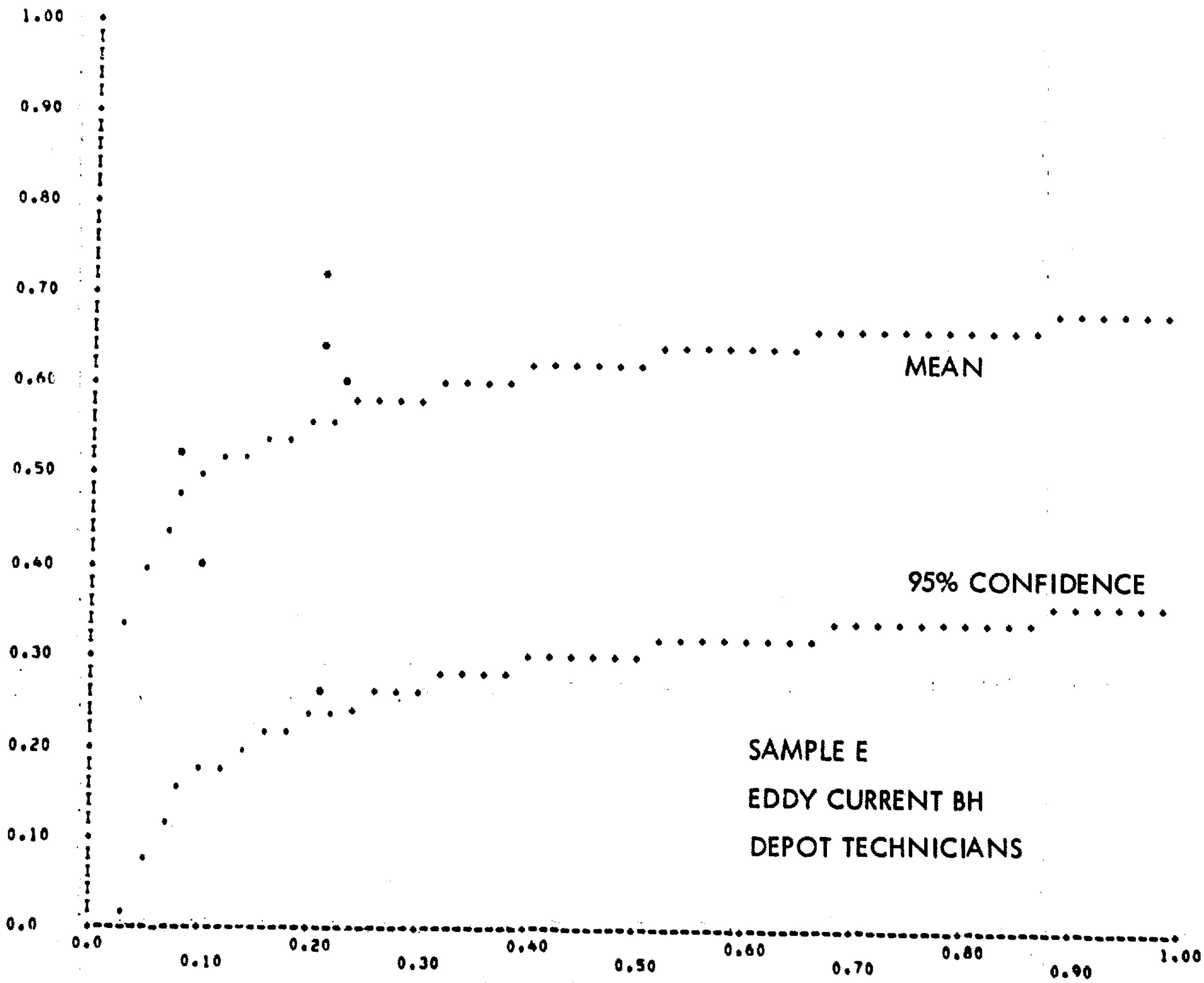


Figure 11-64

SAMPLE: E

METHOD: EH

NO OF INSPECTORS: 5

NO OF FLAWS: 6

INPUT RECORD: 05 E EH 2 3 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW BORE LENGTH (INCHES).

TECH SKILL LEVEL 3 SAMPLE E (EH)

EQUATION Y=A*X**B A = 0.062032 B = 1.120599

COEFFICIENT OF CORRELATION = 0.824 COEFFICIENT OF DETERMINATION = 0.466

STANDARD ERROR OF ESTIMATE = 0.10

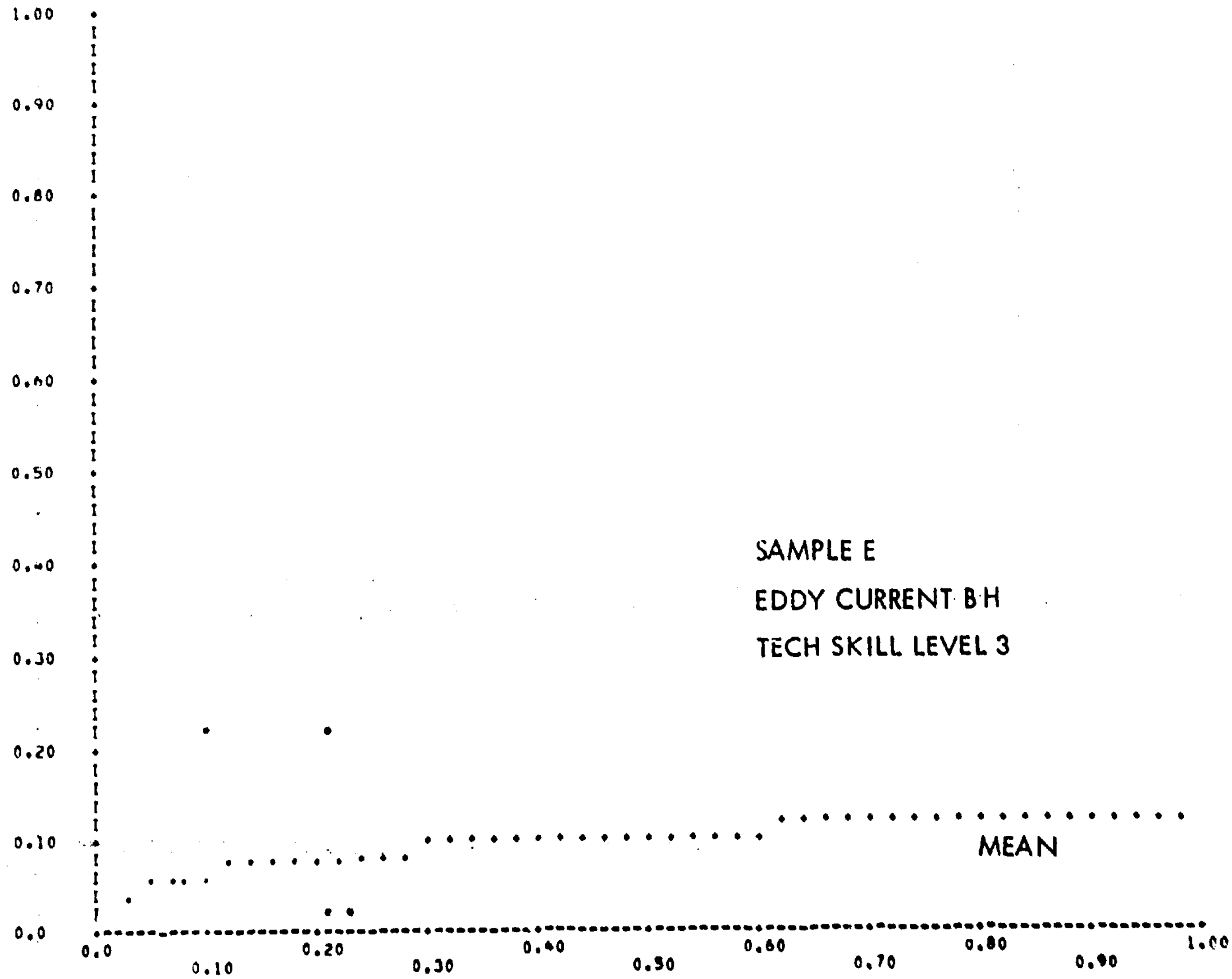


Figure 11-65

SAMPLE: E

METHOD: EH

NO OF INSPECTORS: 83

NO OF FLAWS: 6

INPUT RECORD: 05 E EH 2 5 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW BORE LENGTH (INCHES).

TECH SKILL LEVEL 5 SAMPLE E (EH)

EQUATION Y=A*X**B A = 0.203795 B = 1.241685

COEFFICIENT OF CORRELATION = 0.851 COEFFICIENT OF DETERMINATION = 0.641

STANDARD ERROR OF ESTIMATE = 0.14

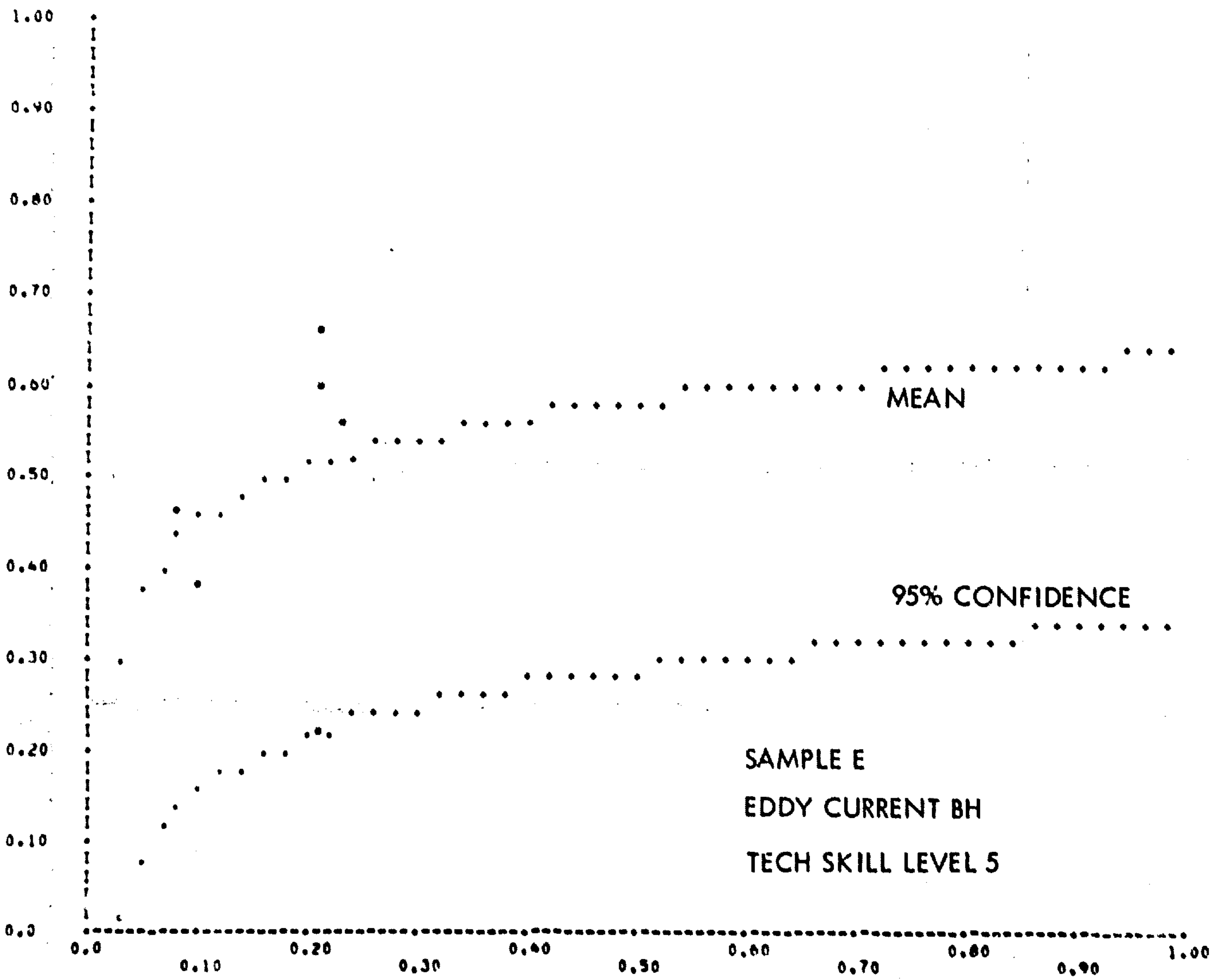


Figure 11-66

SAMPLE: E

METHOD: EH

NO OF INSPECTORS: 15

NO OF FLAWS: 6

INPUT RECORD: 05 E EH 2 7 9K 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW BORE LENGTH (INCHES).

TECH SKILL LEVEL 7 SAMPLE E (EH)

EQUATION Y=A*X**B A = 0.109398 B = 1.642438

COEFFICIENT OF CORRELATION = 0.898 COEFFICIENT OF DETERMINATION = 0.605

STANDARD ERROR OF ESTIMATE = 0.17

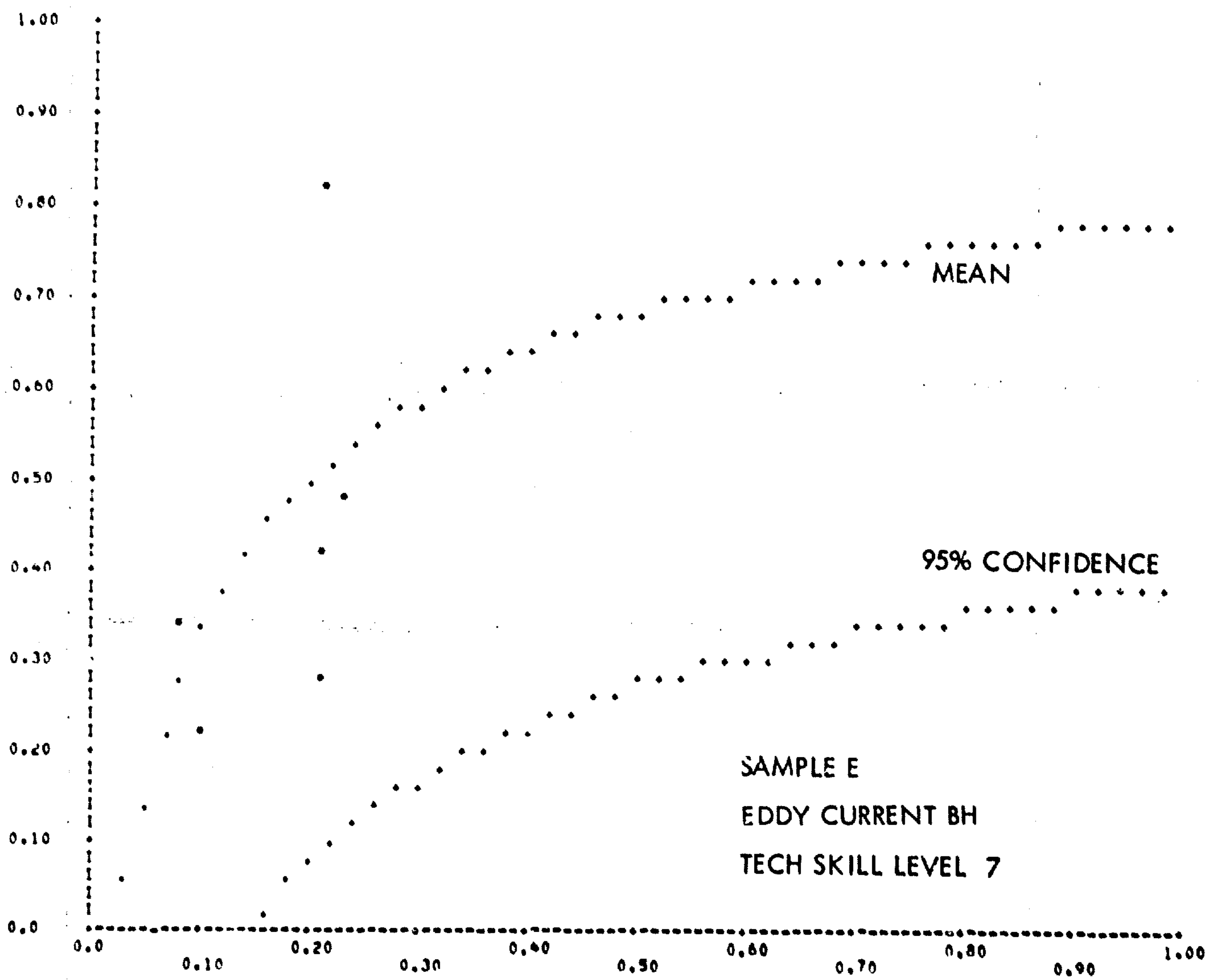


Figure 11-67

SAMPLE: E

METHOD: EH

NO OF INSPECTORS: 11

NO OF FLAWS: 6

INPUT RECORD: 07 E EH 2 N 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW BORE LENGTH (INCHES).

TECH DID NOT GRAD. HS SAMPLE E (EH)

EQUATION Y=A*X**B A = 0.141717 B = 1.506154

COEFFICIENT OF CORRELATION = 0.766 COEFFICIENT OF DETERMINATION = 0.542

STANDARD ERROR OF ESTIMATE = 0.19

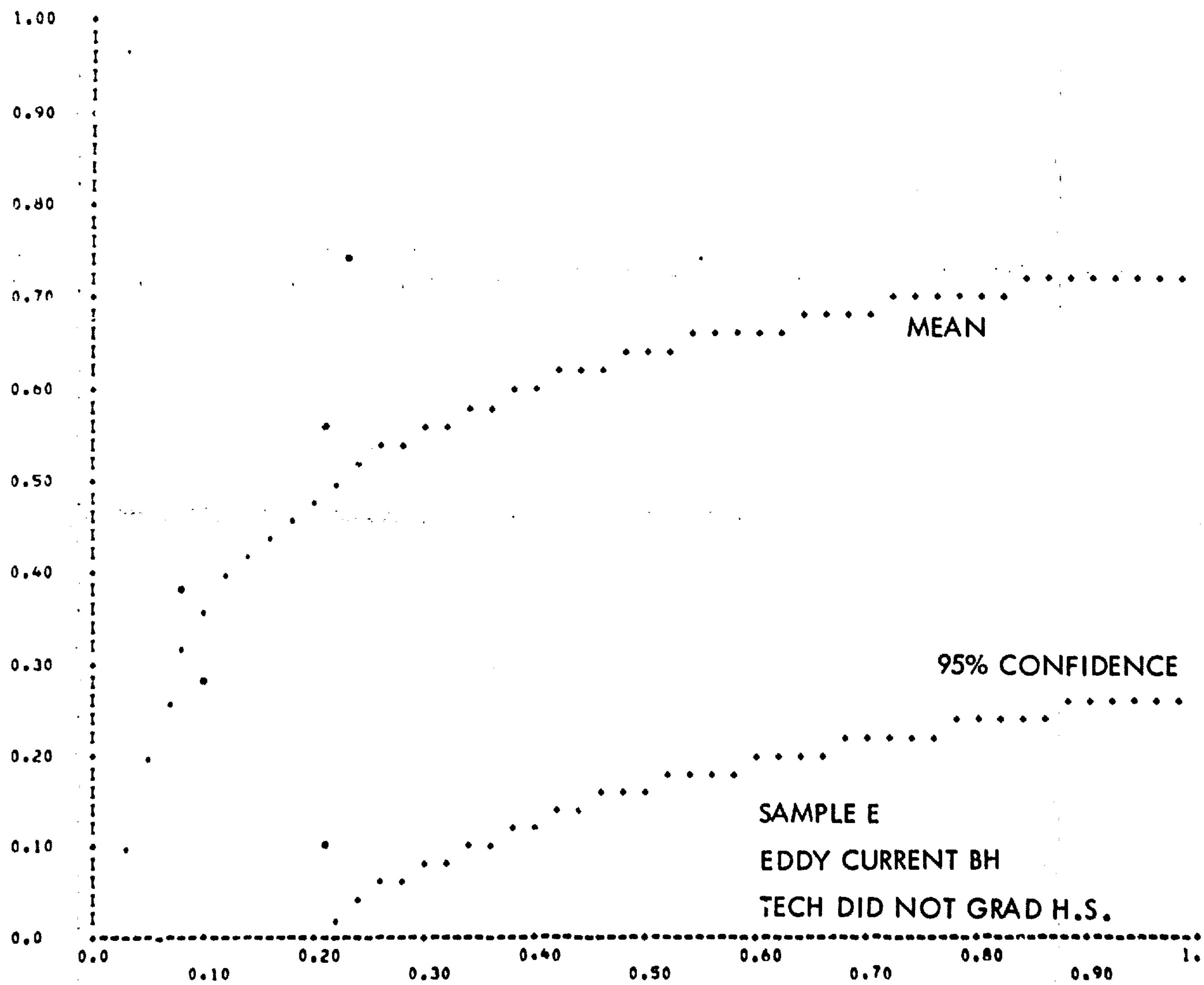


Figure 11-68

SAMPLE: E

METHOD: EH

NO OF INSPECTORS: 22

NO OF FLAWS: 6

INPUT RECORD: 08 E EH 2 150 250 95 10

CONFIDENCE LEVEL: .95

X AXIS IN FLAW BORE LENGTH (INCHES).

TECH UNDER 25YRS AGE SAMPLE E (EH)

EQUATION Y=A*X**B A = 0.527663 B = 1.031128

COEFFICIENT OF CORRELATION = 0.938 COEFFICIENT OF DETERMINATION = 0.803

STANDARD ERROR OF ESTIMATE = 0.08

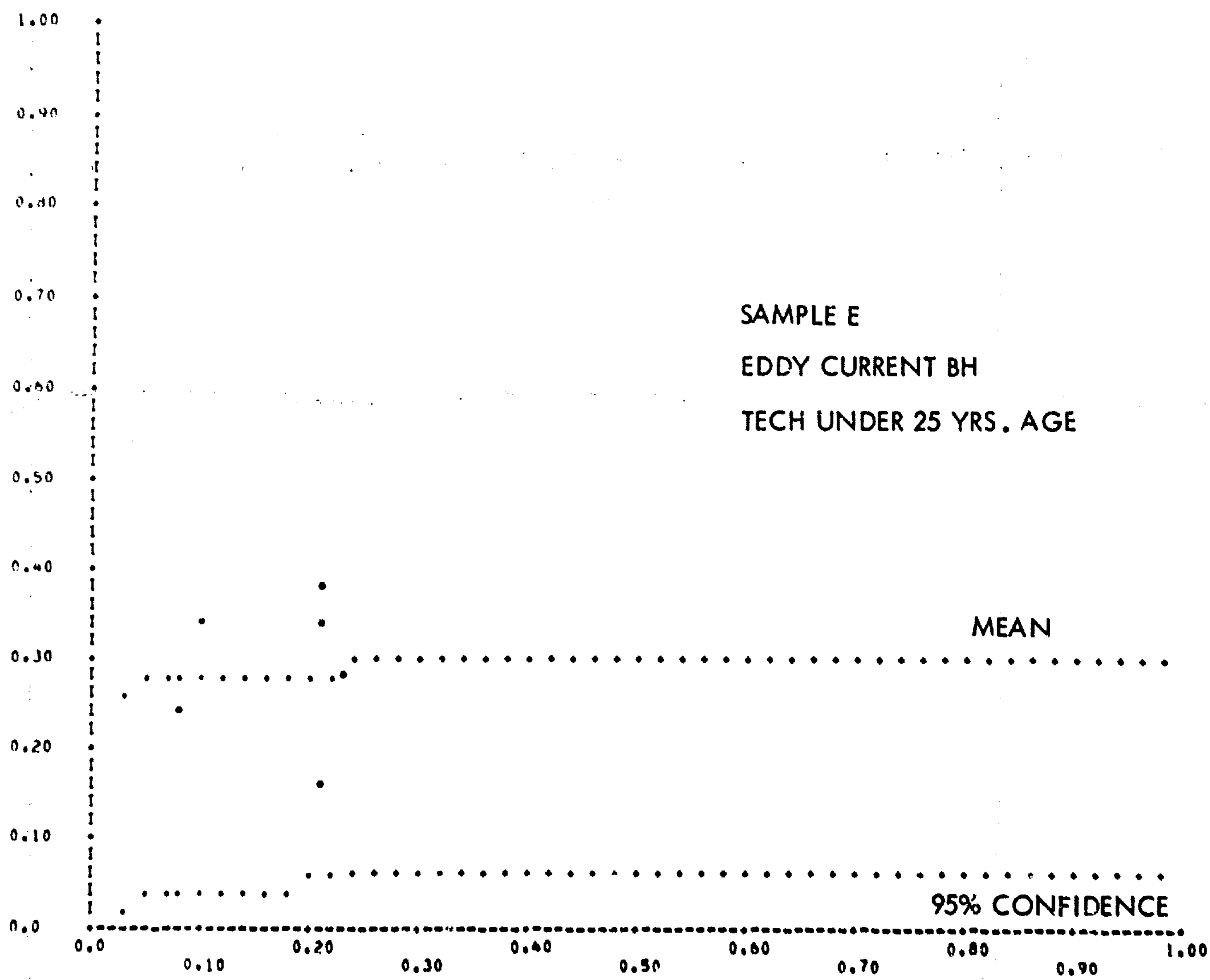


Figure 11-69

SAMPLE: E

METHOD: EH

NO OF INSPECTORS: 31

NO OF FLAWS: 6

INPUT RECORD: 08 E EH 2 400 990 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW BORE LENGTH (INCHES).

TECH OVER 40YRS AGE SAMPLE E (EH)

EQUATION Y=A*X**B A = 0.240165 B = 1.258933

COEFFICIENT OF CORRELATION = 0.766 COEFFICIENT OF DETERMINATION = 0.603

STANDARD ERROR OF ESTIMATE = 0.15

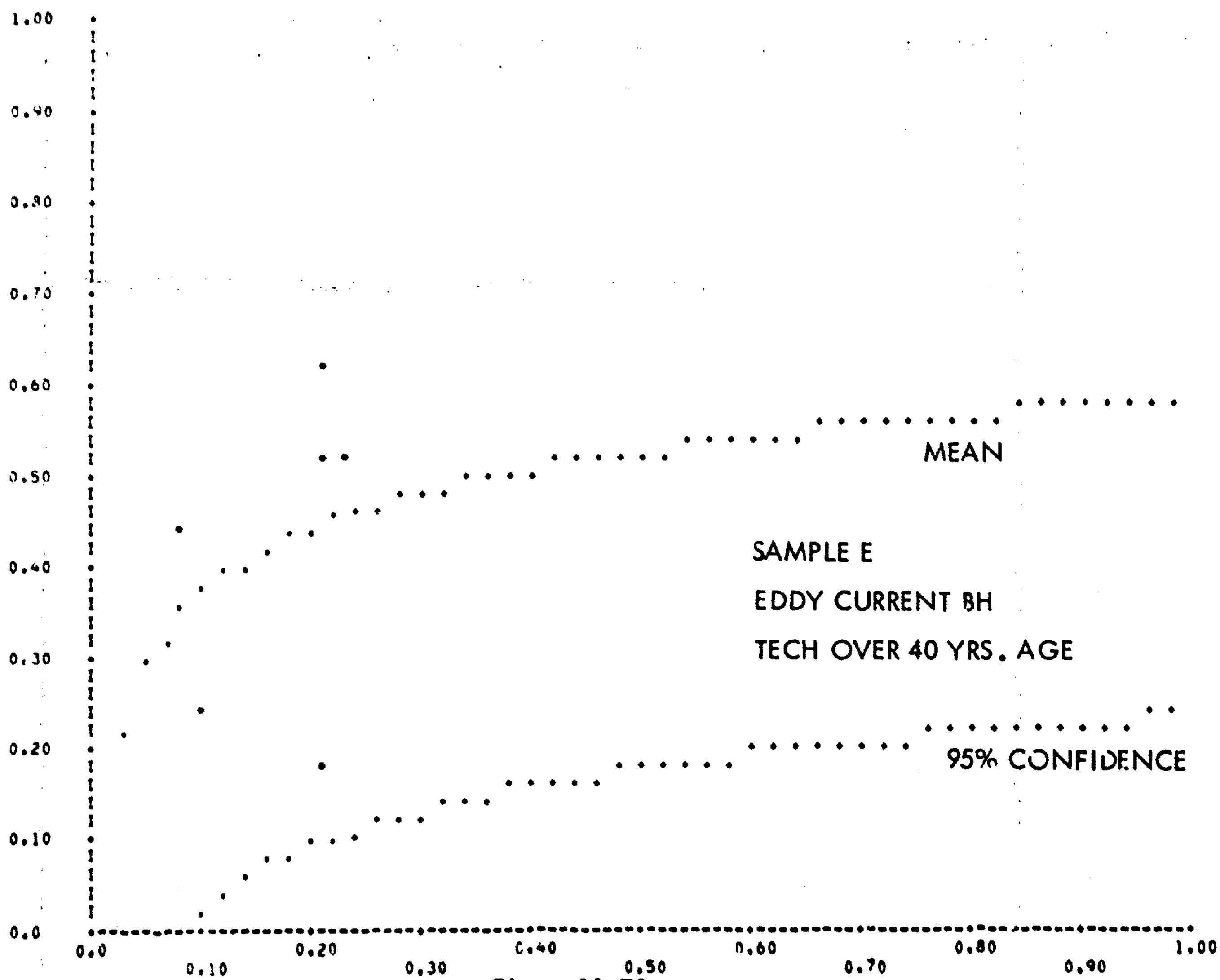


Figure 11-70

SAMPLE: E

METHOD: EH

NO OF INSPECTORS: 20

NO OF FLAWS: 6

INPUT RECORD: 09 E EH 2 000 003 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW BORE LENGTH (INCHES).

TECH 3YRS OR LESS EXPER. SAMPLE E (EH)

EQUATION Y=A*X**B A = 0.339759 B = 0.903935

COEFFICIENT OF CORRELATION = 0.694 COEFFICIENT OF DETERMINATION = 0.475

STANDARD ERROR OF ESTIMATE = 0.14

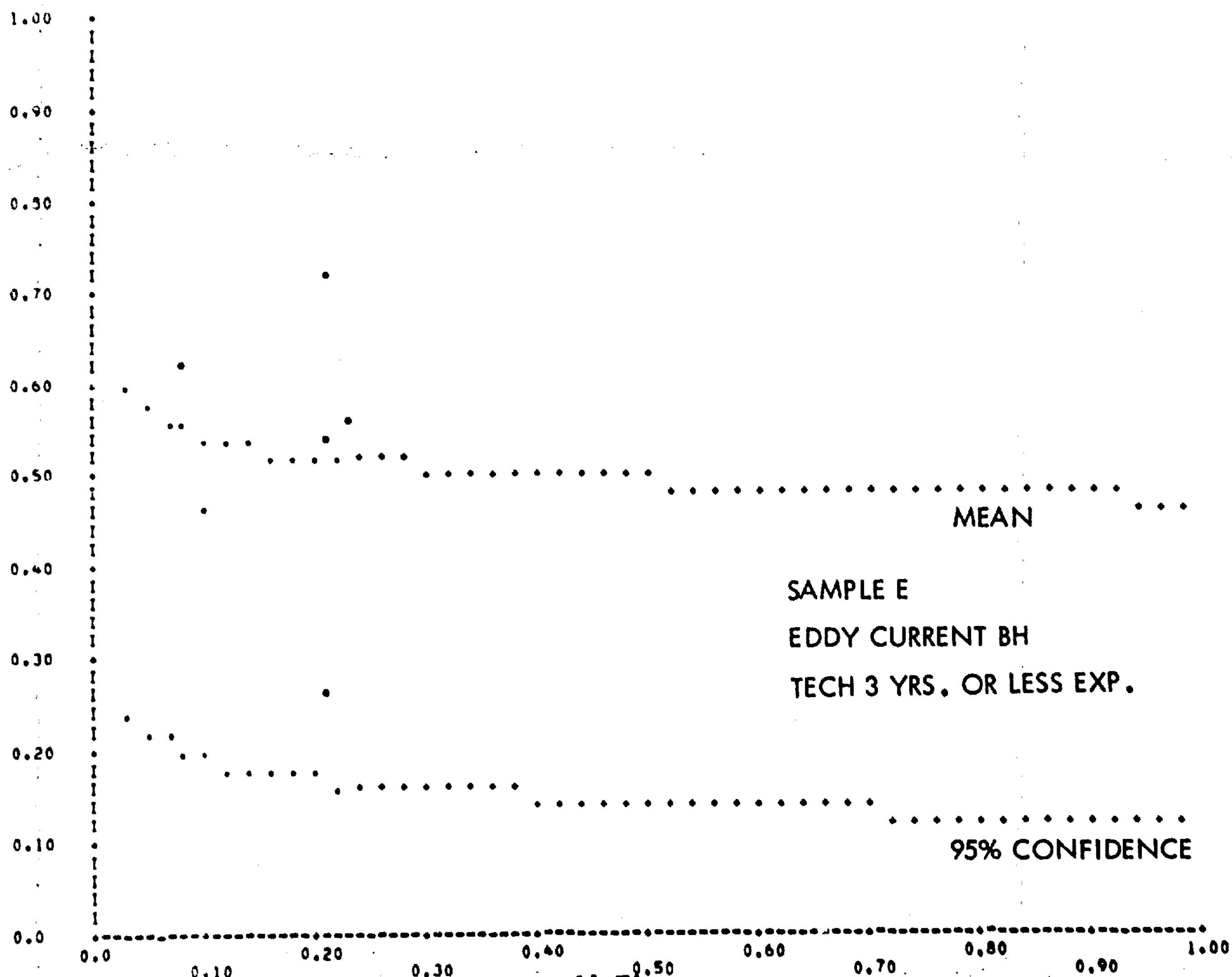


Figure 11-71

SAMPLE: E

METHOD: EH

NO OF INSPECTORS: 71

NO OF FLAWS: 6

INPUT RECORD: 09 E EH 2 011 099 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW BORE LENGTH (INCHES).

TECH OVER 10 YRS EXPER. SAMPLE E (EH)

EQUATION Y=A*X**B A = 0.188162 B = 1.352766

COEFFICIENT OF CORRELATION - 0.936 COEFFICIENT OF DETERMINATION - 0.762

STANDARD ERROR OF ESTIMATE - 0.12

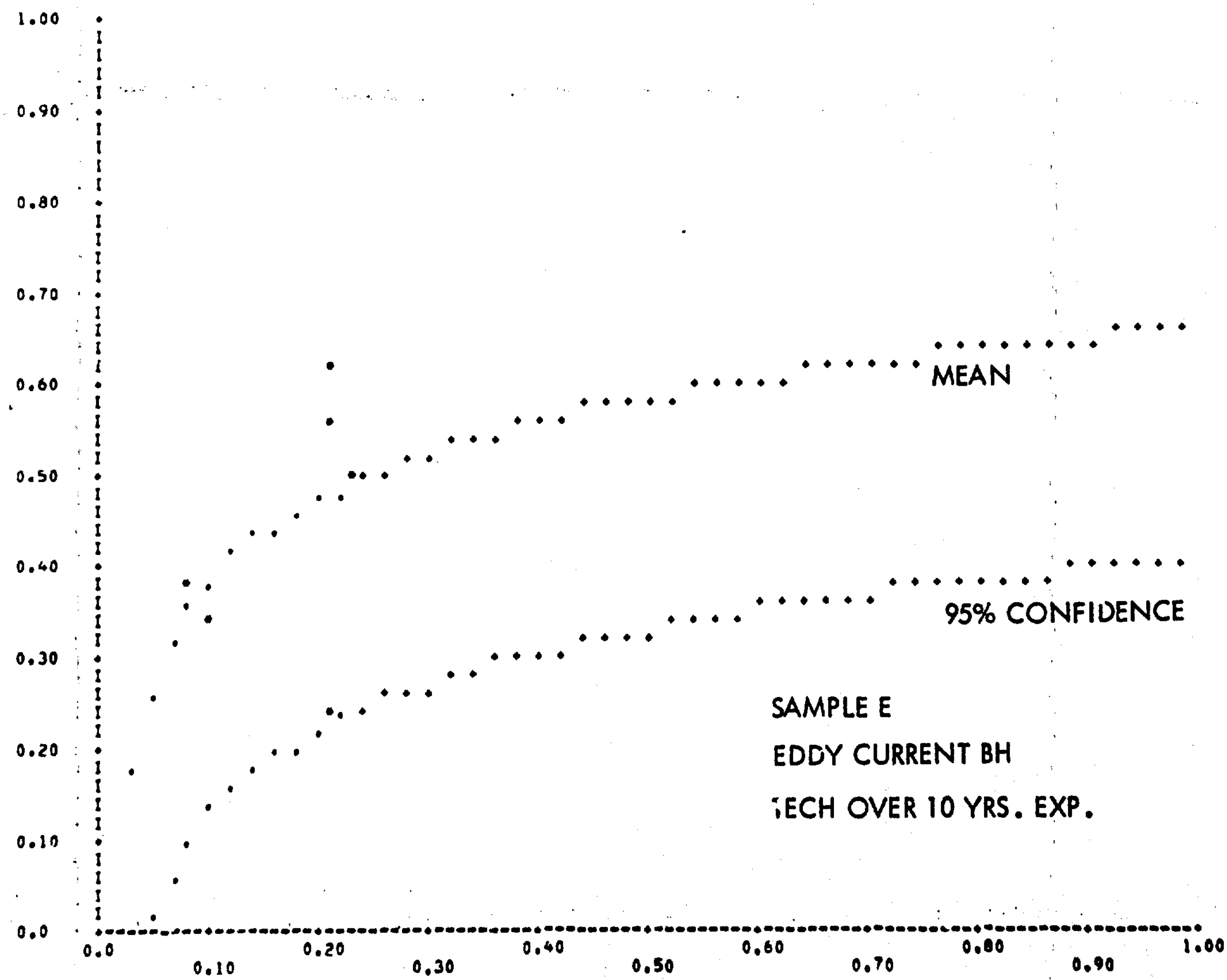


Figure 11-72

SAMPLE: E

METHOD: EH

NO OF INSPECTORS: 48

NO OF FLAWS: 6

INPUT RECORD: 10 E EH 2 000 200 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW BORE LENGTH (INCHES).

TECH 0-200HRS NDI TRNG SAMPLE E (EH)

EQUATION Y=A*X**B A = 0.172014 B = 1.248150

COEFFICIENT OF CORRELATION - 0.795 COEFFICIENT OF DETERMINATION - 0.596

STANDARD ERROR OF ESTIMATE - 0.15

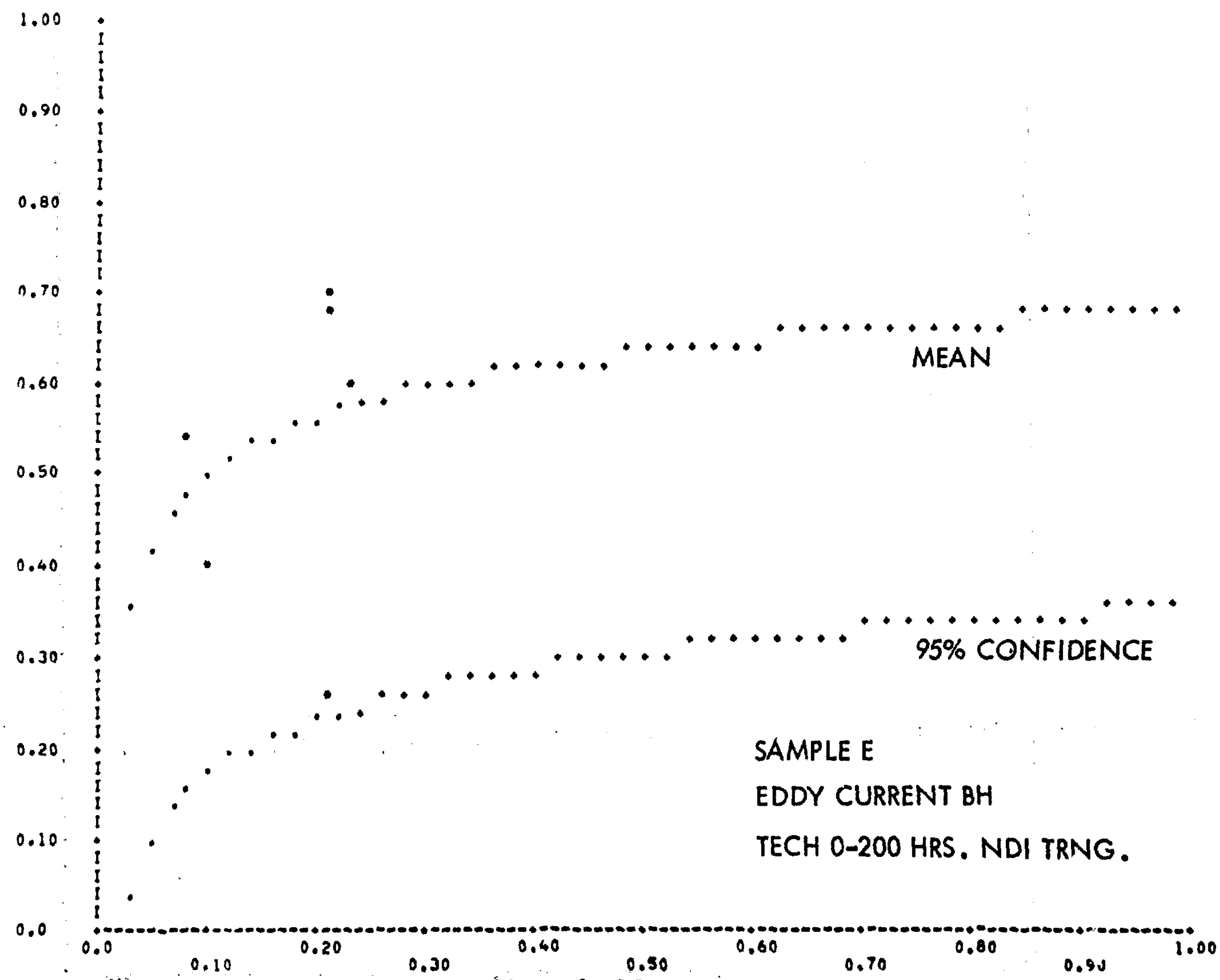


Figure 11-73

SAMPLE: E

METHOD: EH

NO OF INSPECTORS: 17

NO OF FLAWS: 6

INPUT RECORD: 10 E EH 2 500 999 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW BORE LENGTH (INCHES).

TECH 500+ HRS NDI TRNG SAMPLE E (EH)

EQUATION Y=A*X**B A = 0.180351 B = 1.413530

COEFFICIENT OF CORRELATION = 0.936 COEFFICIENT OF DETERMINATION = 0.726

STANDARD ERROR OF ESTIMATE = 0.13

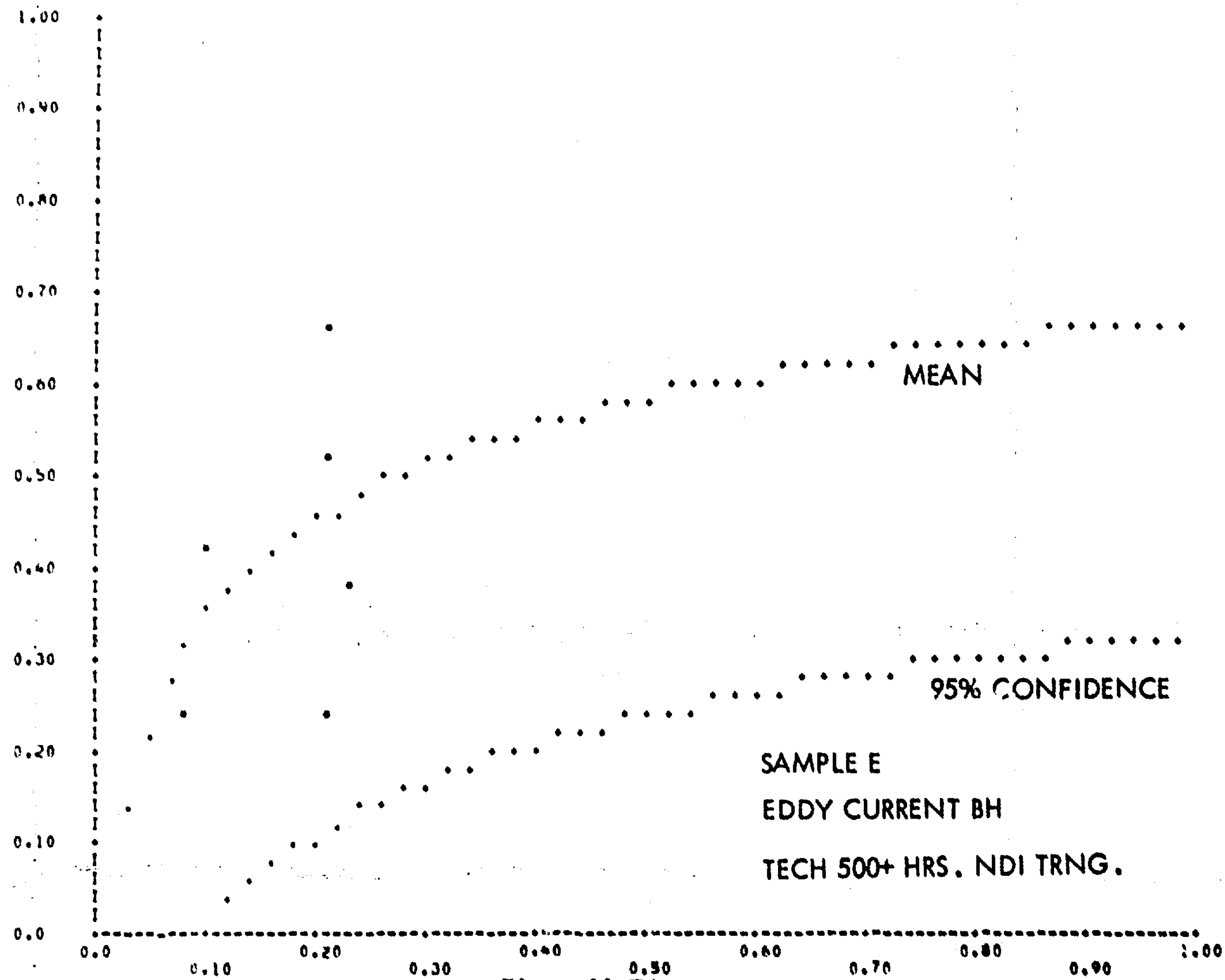


Figure 11-74

SAMPLE: F

METHOD: EH

NO OF INSPECTORS: 79

NO OF FLAWS: 34

INPUT RECORD: 01 F EH 2 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW BORE LENGTH (INCHES).

ALL TECH. SAMPLE F (EH)

EQUATION Y=A*X**B A = 0.378160 B = 1.181222

COEFFICIENT OF CORRELATION = 0.960 COEFFICIENT OF DETERMINATION = 0.965

STANDARD ERROR OF ESTIMATE = 0.06

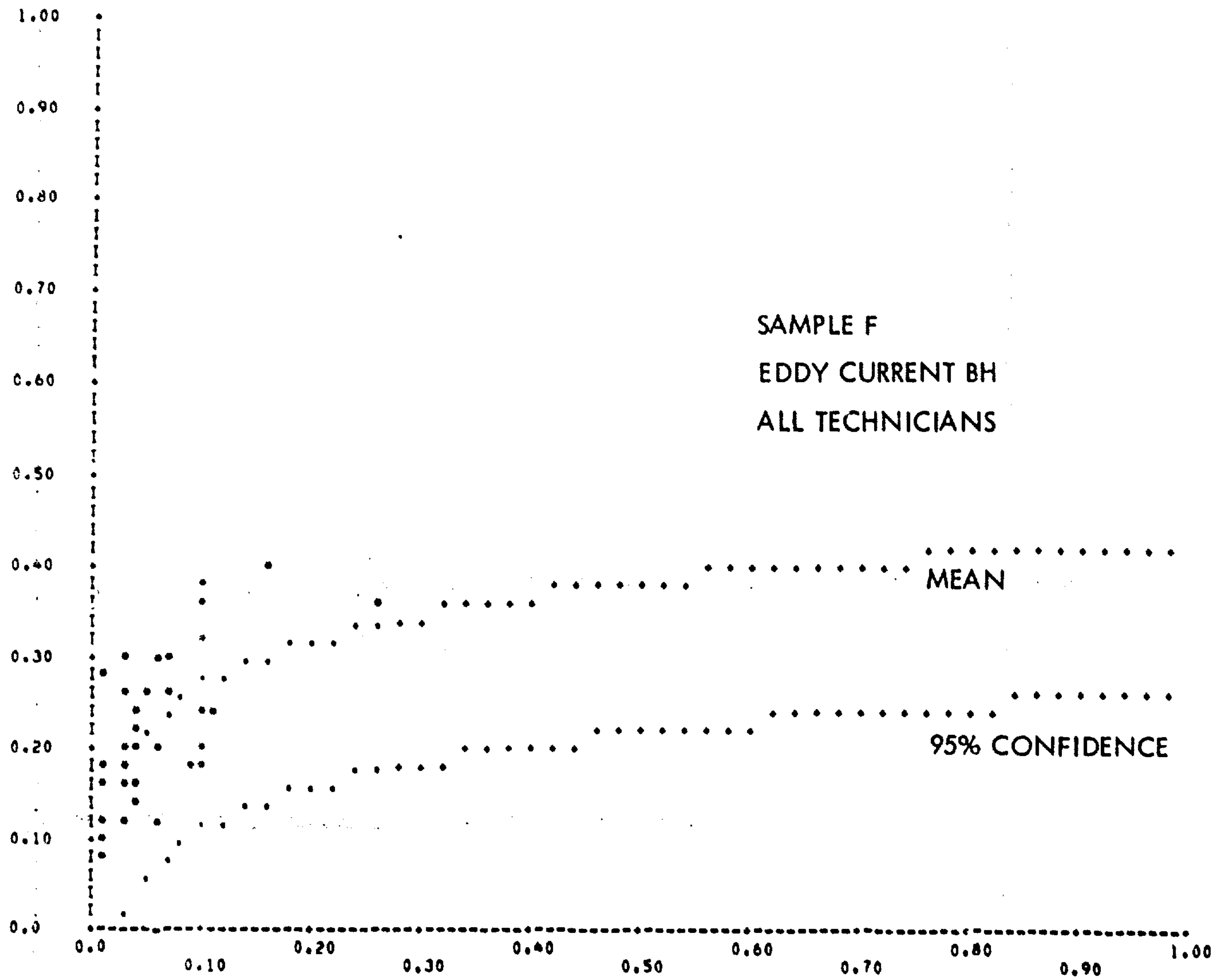


Figure 11-75

SAMPLE: F

METHOD: EH

NO OF INSPECTORS: 38

NO OF FLAWS: 34

INPUT RECORD: 02 F EH 2 17 99 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW BORE LENGTH (INCHES).

UPPER 50% ALL TECH SAMPLE F (EH)

EQUATION Y=A*X**B A = 0.222140 B = 1.219797

COEFFICIENT OF CORRELATION = 0.966 COEFFICIENT OF DETERMINATION = 0.935

STANDARD ERROR OF ESTIMATE = 0.10

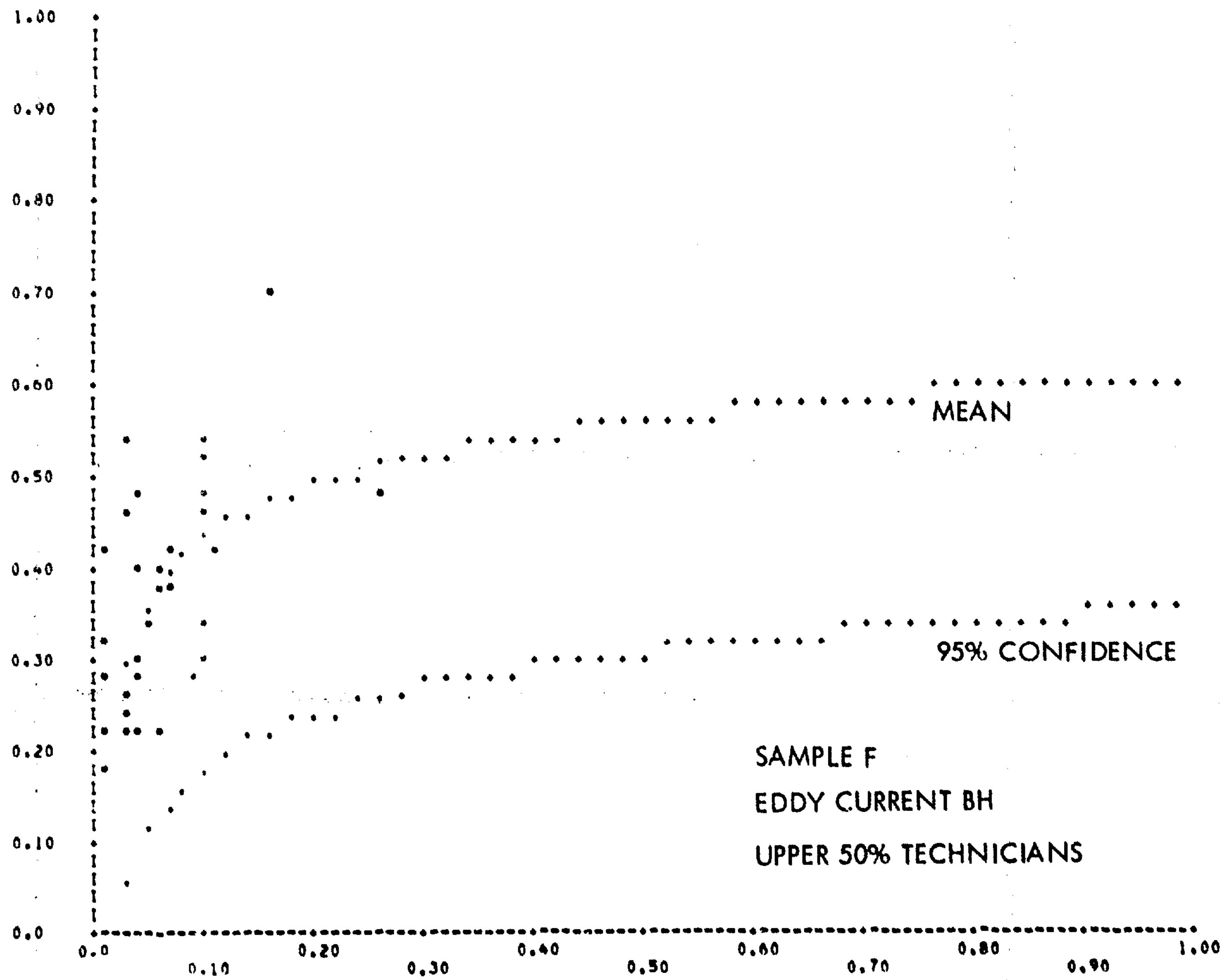


Figure 11-76

SAMPLE: F

METHOD: EH

NO OF INSPECTORS: 47

NO OF FLAWS: 34

INPUT RECORD: 03 F EH 2 D 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW BORE LENGTH (INCHES),

DEPOT TECH SAMPLE F (EH)

EQUATION Y=A*X**B A = 0.302712 B = 1.211781

COEFFICIENT OF CORRELATION = 0.912 COEFFICIENT OF DETERMINATION = 0.932

STANDARD ERROR OF ESTIMATE = 0.10

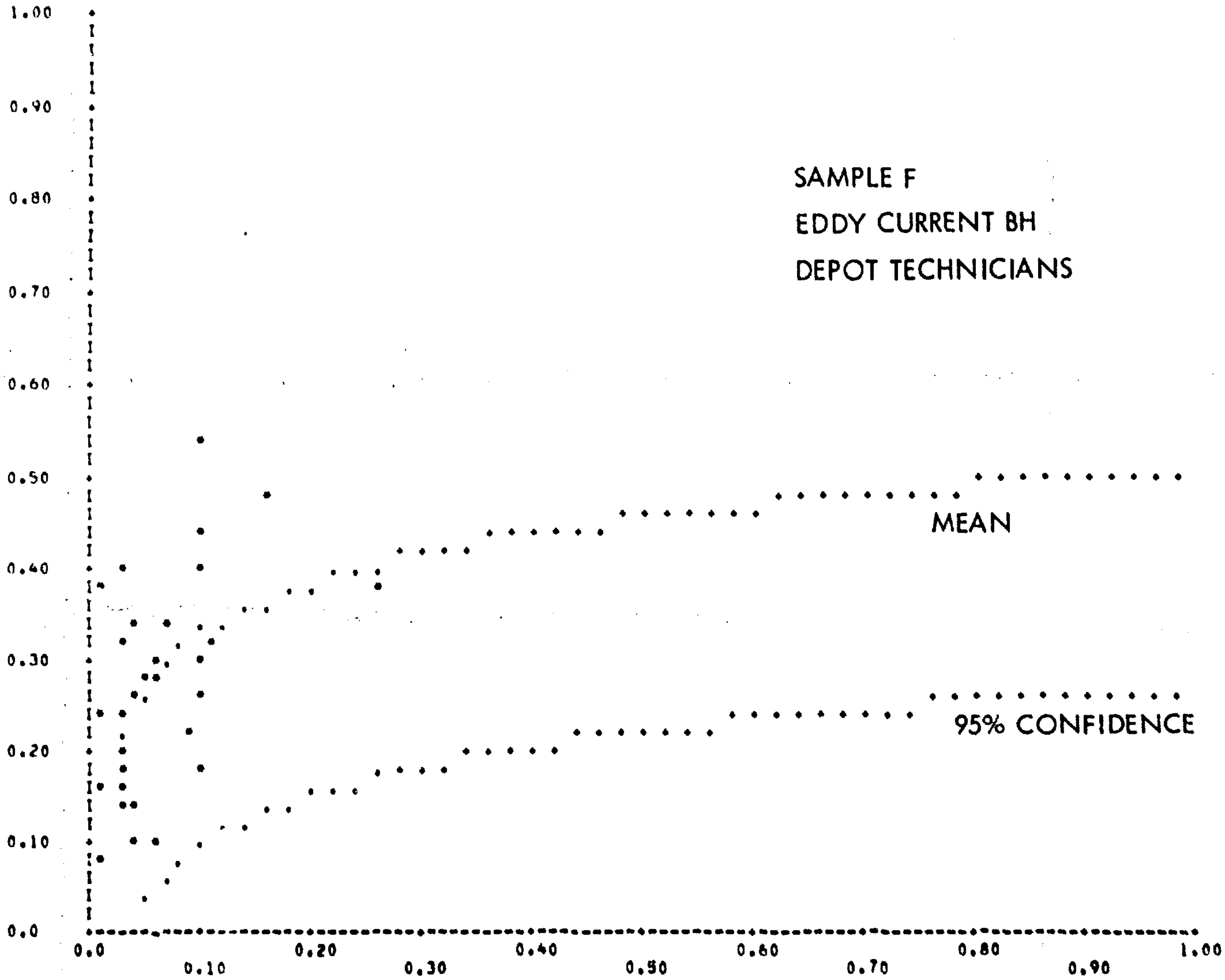


Figure 11-77

SAMPLE: F

METHOD: EH

NO OF INSPECTORS: 64

NO OF FLAWS: 34

INPUT RECORD: 05 F EH 2 5 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW HOLE LENGTH (INCHES).

TECH SKILL LEVEL 5 SAMPLE F (EH)

EQUATION Y=A*X**B A = 0.352839 B = 1.188885

COEFFICIENT OF CORRELATION = 0.947 COEFFICIENT OF DETERMINATION = 0.952

STANDARD ERROR OF ESTIMATE = 0.08

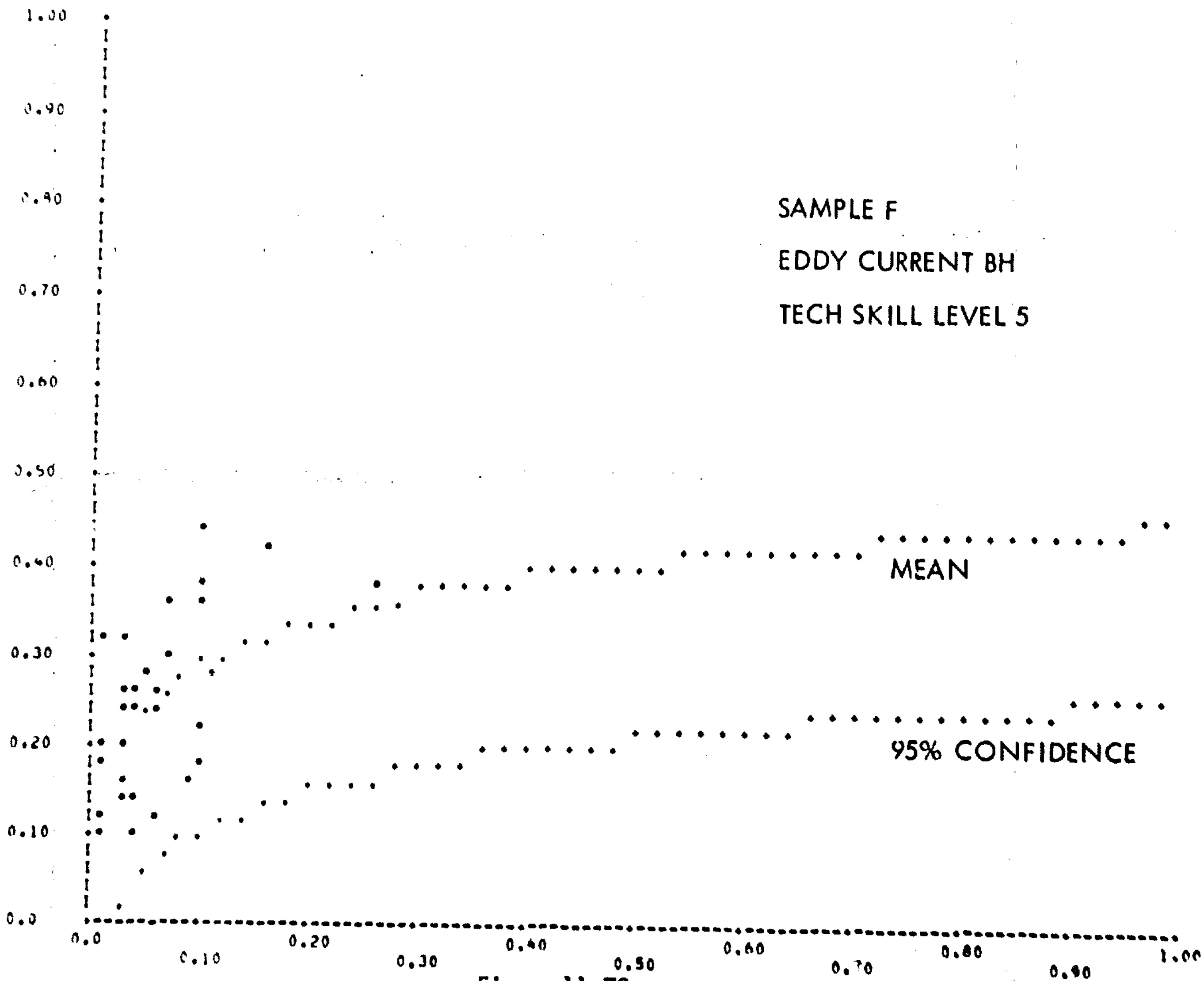


Figure 11-78

SAMPLE: F

METHOD: EH

NO OF INSPECTORS: 13

NO OF FLAWS: 34

INPUT RECORD: 05 F EH 2 7 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW BORE LENGTH (INCHES).

TECH SKILL LEVEL 7 SAMPLE F (EH)

EQUATION Y=A*X**B A = 0.560565 B = 1.145838

COEFFICIENT OF CORRELATION = 0.880 COEFFICIENT OF DETERMINATION = 0.860

STANDARD ERROR OF ESTIMATE = 0.10

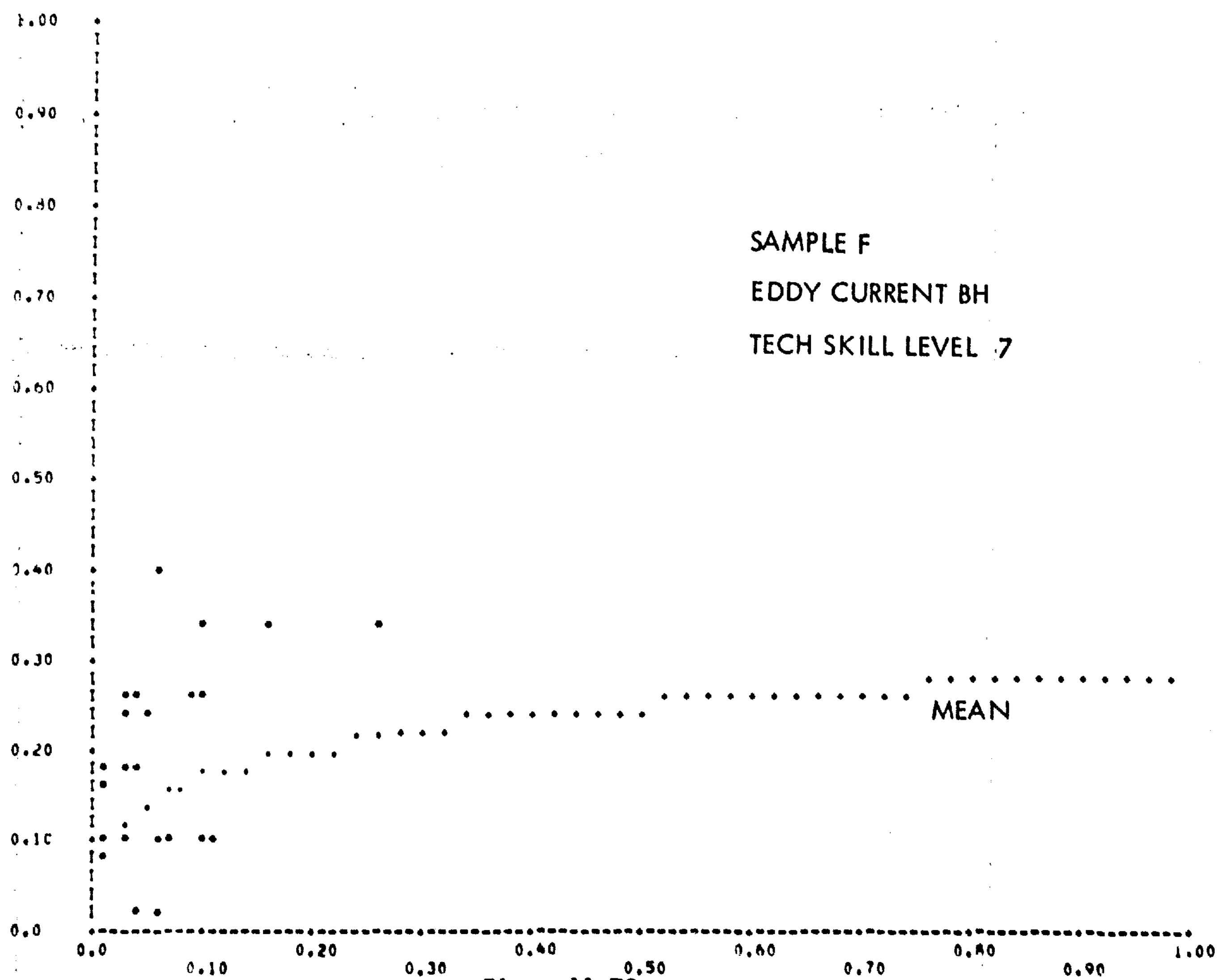


Figure 11-79

SAMPLE: F

METHOD: EH

NO OF INSPECTORS: 6

NO OF FLAWS: 34

INPUT RECORD: 07 F EH 2 N 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW BORE LENGTH (INCHES).

TECH DID NOT GRAD. HS SAMPLE F (EH)

EQUATION Y=A*X**B A = 0.209449 B = 1.379441

COEFFICIENT OF CORRELATION = 0.774 COEFFICIENT OF DETERMINATION = 0.771

STANDARD ERROR OF ESTIMATE = 0.18

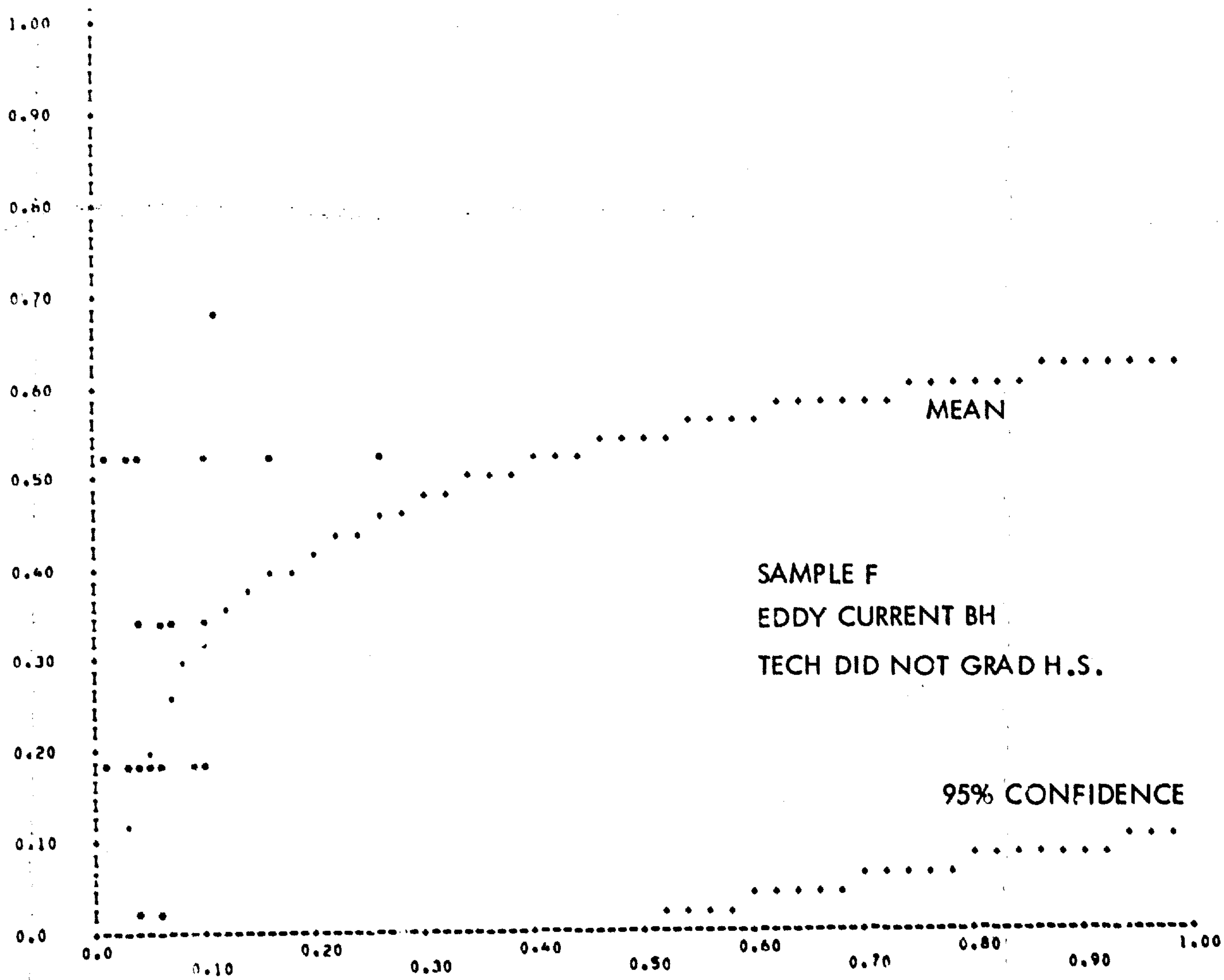


Figure 11-80

SAMPLE: F

METHOD: EH

NO OF INSPECTORS: 11

NO OF FLAWS: 34

INPUT RECORD: 0A F EH 2 150 250 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW BORE LENGTH (INCHES).

TECH UNDER 25YRS AGE SAMPLE F (EH)

EQUATION Y=A*X**B A = 0.783099 B = 1.042162

COEFFICIENT OF CORRELATION = 0.830 COEFFICIENT OF DETERMINATION = 0.851

STANDARD ERROR OF ESTIMATE = 0.09

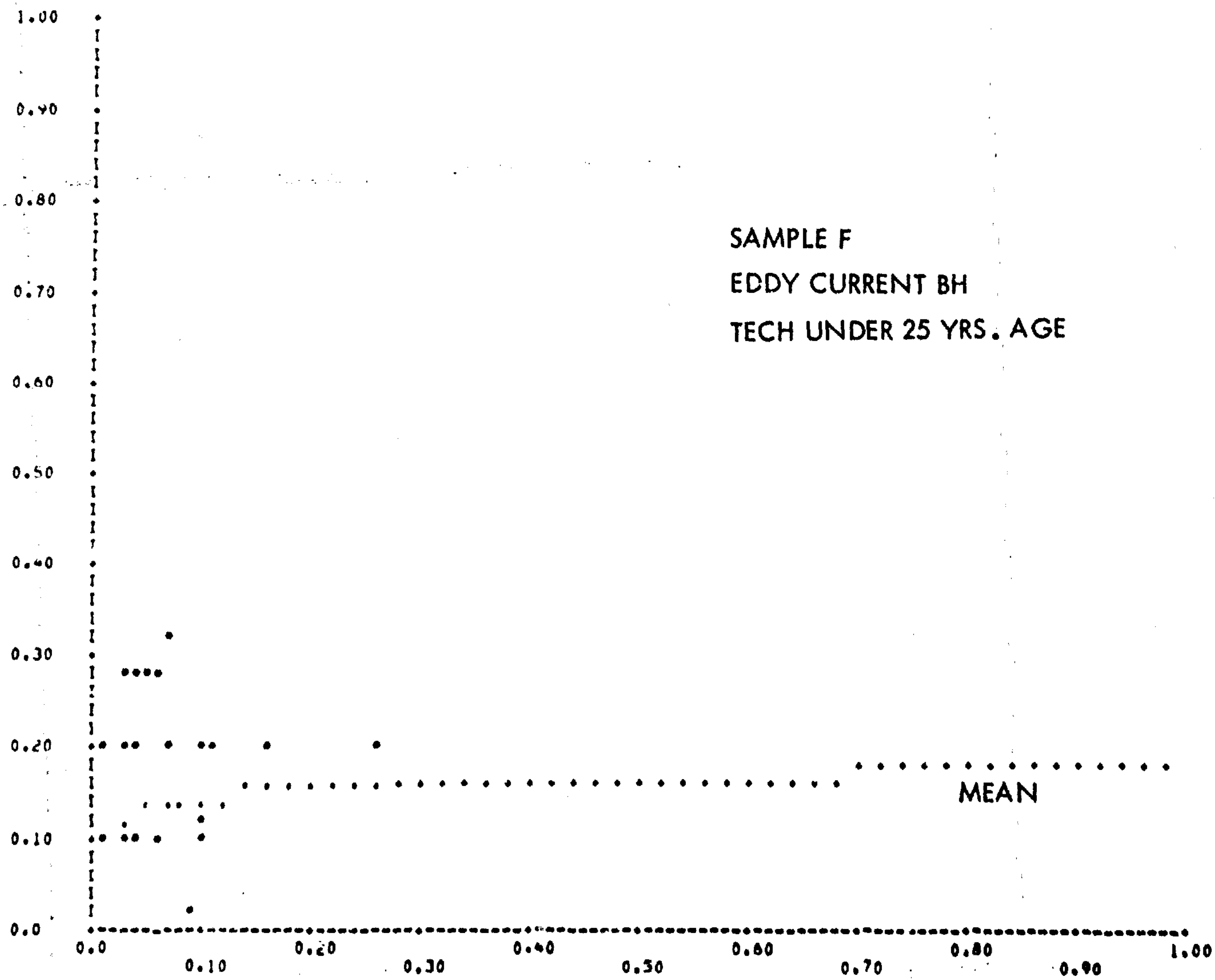


Figure 11-81

SAMPLE: F

METHOD: EH

NO OF INSPECTORS: 30

NO OF FLAWS: 34

INPUT RECORD: 08 F EH 2 400 990 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW BORE LENGTH (INCHES).

TECH OVER 40YRS AGE SAMPLE F (EH)

EQUATION Y=A*X**B A = 0.321778 B = 1.223173

COEFFICIENT OF CORRELATION = 0.935 COEFFICIENT OF DETERMINATION = 0.930

STANDARD ERROR OF ESTIMATE = 0.10

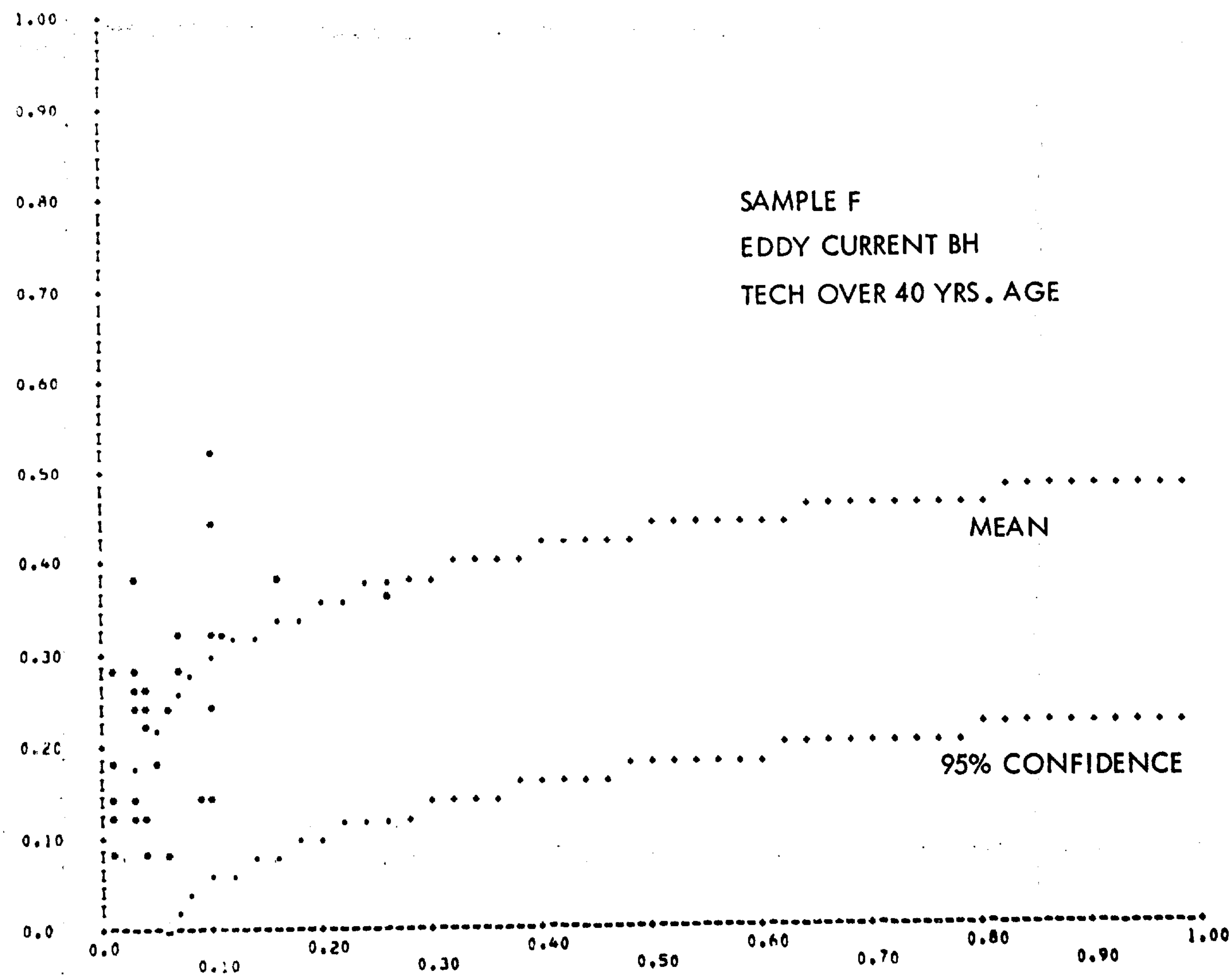


Figure 11-82

SAMPLE: F

METHOD: EH

NO OF INSPECTORS: 22

NO OF FLAWS: 34

INPUT RECORD: 09 F EH 2 000 003 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW BORE LENGTH (INCHES).

TECH 3YRS OR LESS EXPER. SAMPLE F (EH)

EQUATION Y=A*X**B A = 0.597289 B = 1.070302

COEFFICIENT OF CORRELATION = 0.876 COEFFICIENT OF DETERMINATION = 0.864

STANDARD ERROR OF ESTIMATE = 0.11

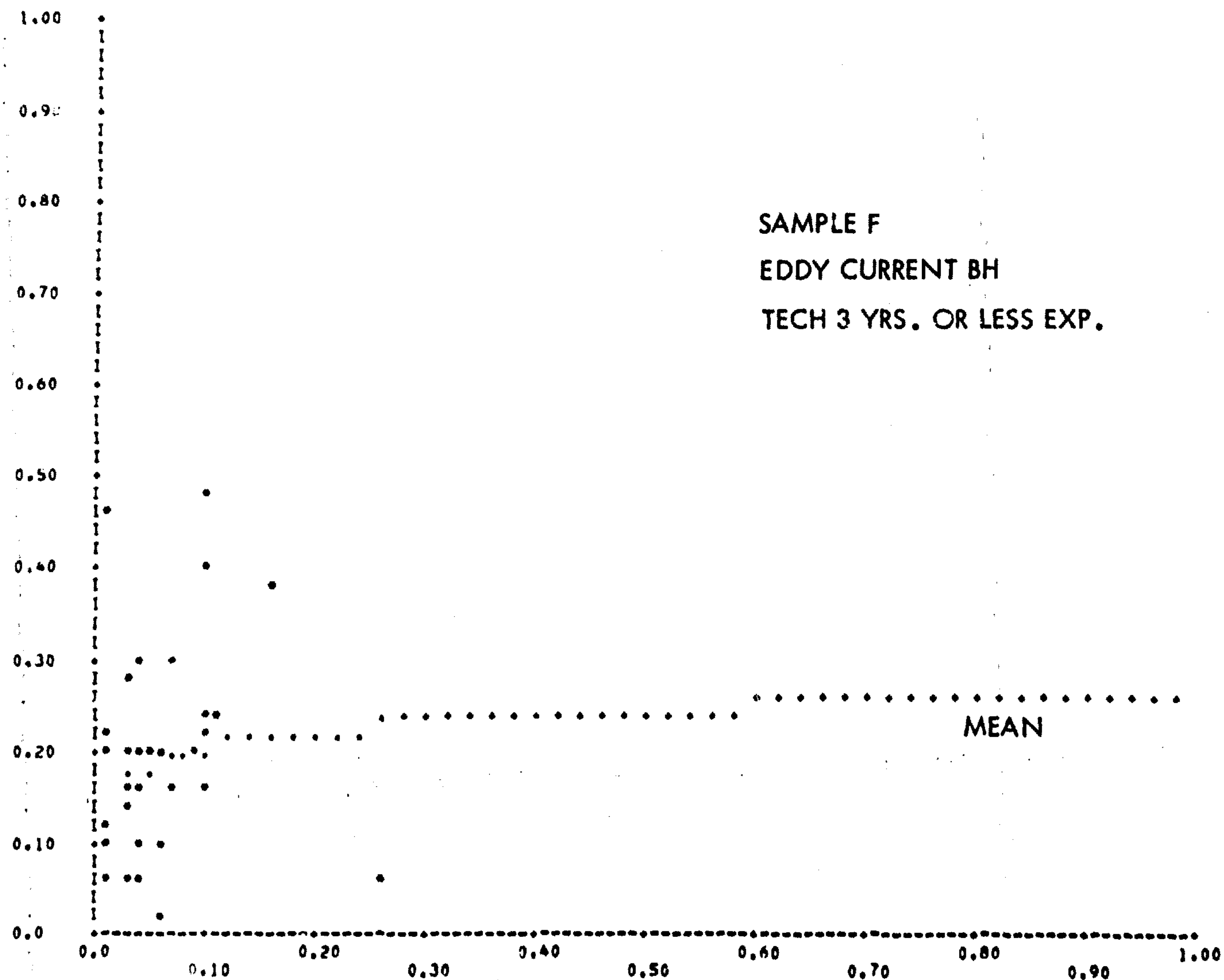


Figure 11-83

SAMPLE: F

METHOD: EH

NO OF INSPECTORS: 46

NO OF FLAWS: 34

INPUT RECORD: 09 F EH 2 011 099 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW BORE LENGTH (INCHES).

TECH OVER 10 YRS EXPER. SAMPLE F (EH)

EQUATION Y=A*X**B A = 0.327026 B = 1.237574

COEFFICIENT OF CORRELATION = 0.959 COEFFICIENT OF DETERMINATION = 0.944

STANDARD ERROR OF ESTIMATE = 0.09

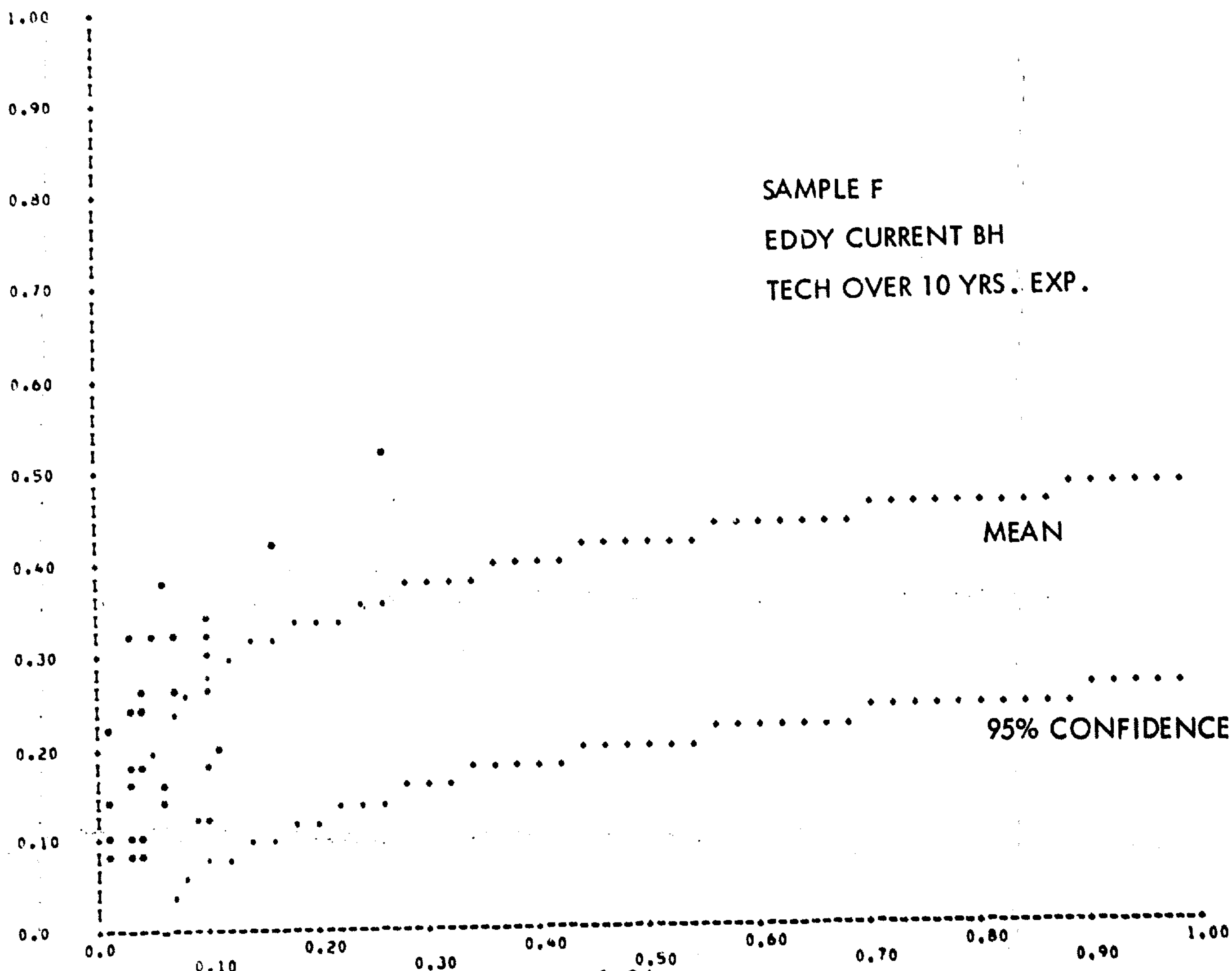


Figure 11-84

SAMPLE: F

METHOD: EH

NO OF INSPECTORS: 42

NO OF FLAWS: 34

INPUT RECORD: 10 F EH 2 000 200 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW BORE LENGTH (INCHES).

TECH 0-200HRS NDI TRNG SAMPLE F (EH)

EQUATION Y=A*X**B A = 0.336052 B = 1.188551

COEFFICIENT OF CORRELATION = 0.922 COEFFICIENT OF DETERMINATION = 0.936

STANDARD ERROR OF ESTIMATE = 0.09

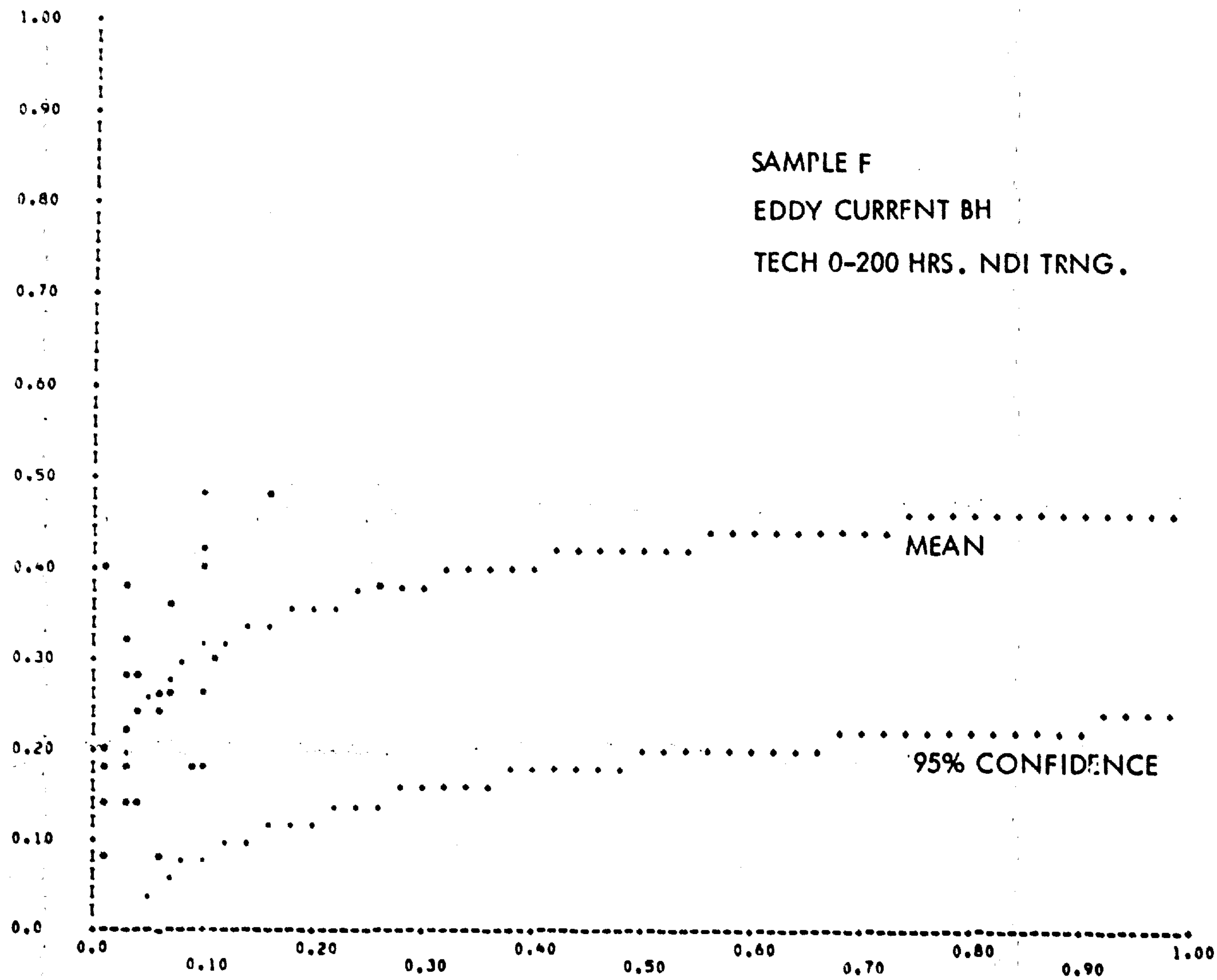


Figure 11-85

SAMPLE: F

METHOD: EH

NO OF INSPECTORS: 9

NO OF FLAWS: 34

INPUT RECORD: 10 F EH 2 500 999 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW BORE LENGTH (INCHES).

TECH 500+ HRS NDI TRNG SAMPLE F (EH)

EQUATION Y=A*X**B A = 0.479882 B = 1.274493

COEFFICIENT OF CORRELATION - 0.933 COEFFICIENT OF DETERMINATION - 0.869

STANDARD ERROR OF ESTIMATE - 0.10

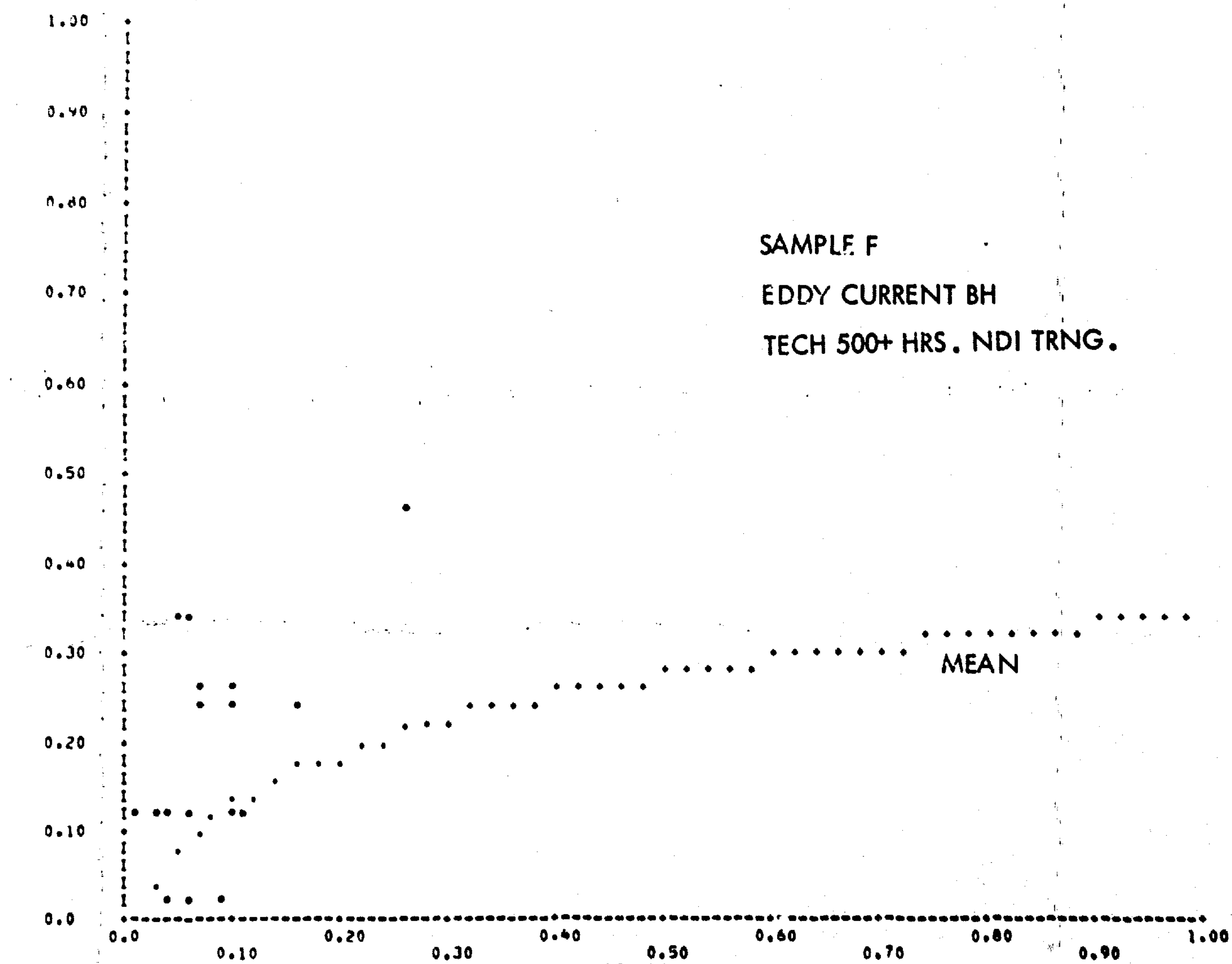


Figure 11-86

SAMPLE: F

METHOD: UT

NO OF INSPECTORS: 8

NO OF FLAWS: 34

INPUT RECORD: 02 F UT 1 09 99 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).

UPPER 50% ALL TECH SAMPLE F (UT)

EQUATION Y=A*X**B A = 0.610479 B = 1.117405

COEFFICIENT OF CORRELATION = 0.819 COEFFICIENT OF DETERMINATION = 0.868

STANDARD ERROR OF ESTIMATE = 0.14

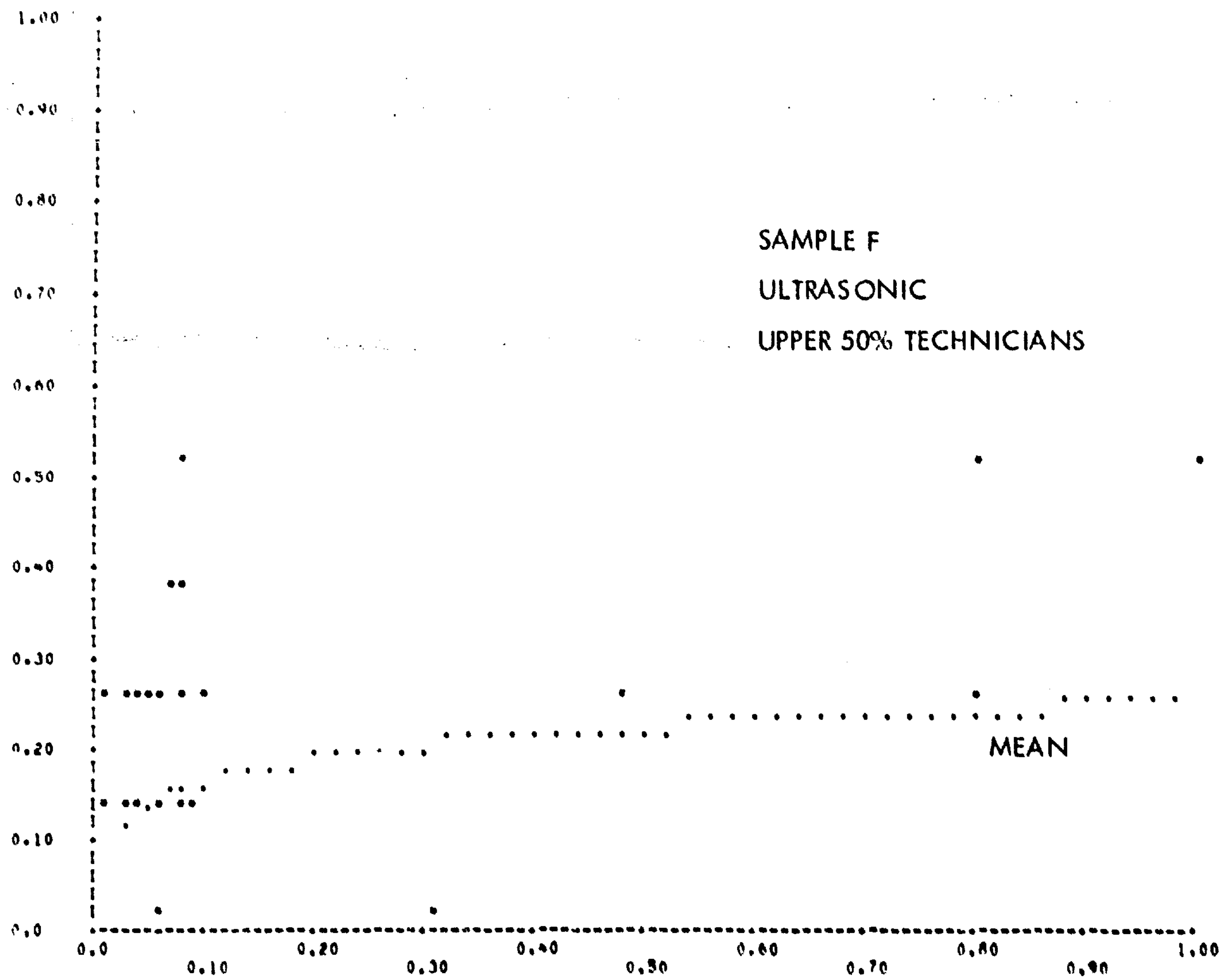


Figure 11-88

SAMPLE: F

METHOD: UT

NO OF INSPECTORS: 13

NO OF FLAWS: 34

INPUT RECORD: 03 F UT 1 D 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).

DEPOT TECH SAMPLE F (UT)

EQUATION Y=A*X**B A = 0.663836 B = 1.145737

COEFFICIENT OF CORRELATION = 0.897 COEFFICIENT OF DETERMINATION = 0.926

STANDARD ERROR OF ESTIMATE = 0.10

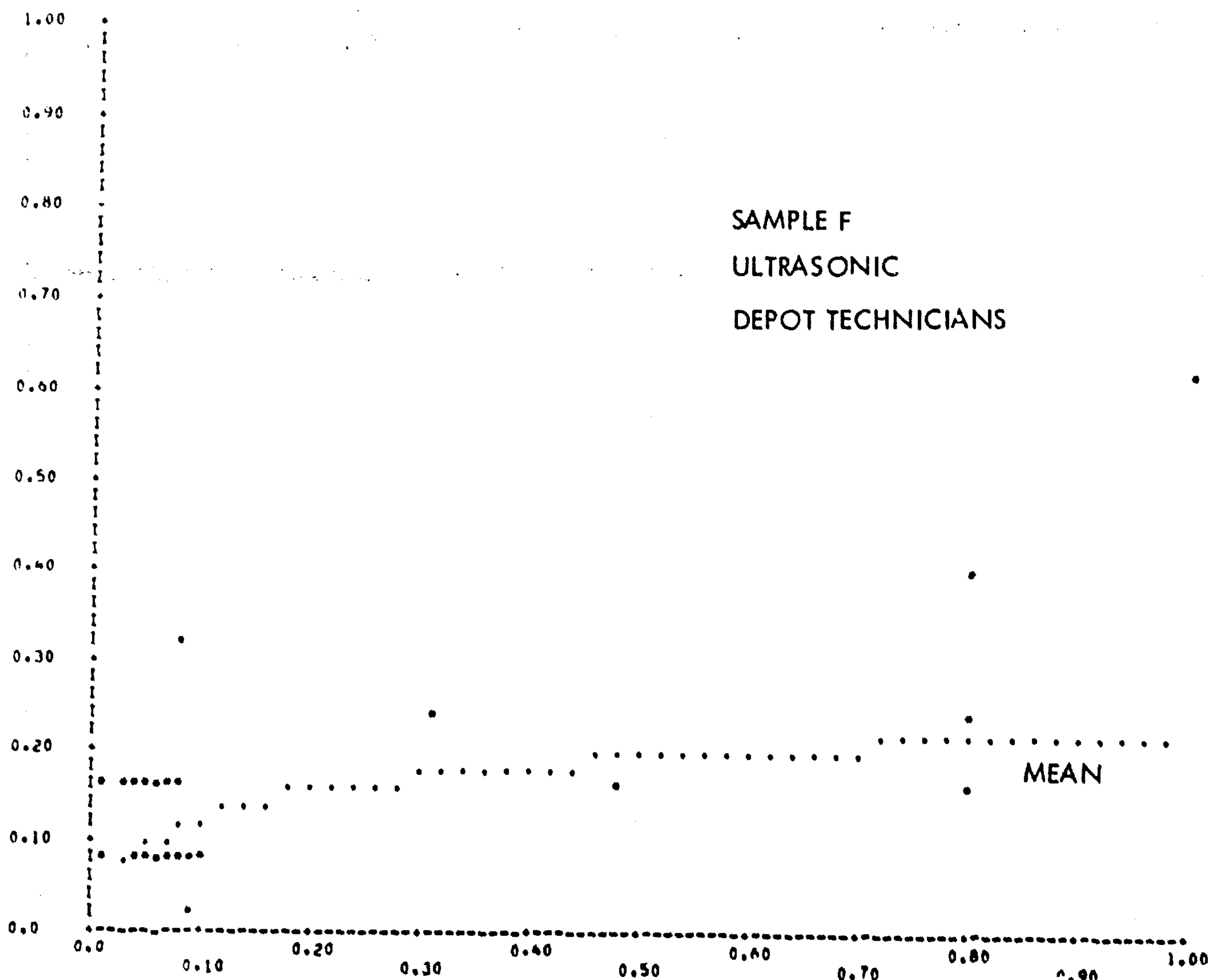


Figure 11-89

SAMPLE: F

METHOD: UT

NO OF INSPECTORS: 20

NO OF FLAWS: 34

INPUT RECORD: 05 F UT 1 5 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).

TECH SKILL LEVEL 5 SAMPLE F (UT)

EQUATION Y=A*X**B A = 0.660415 B = 1.178591

COEFFICIENT OF CORRELATION = 0.939 COEFFICIENT OF DETERMINATION = 0.925

STANDARD ERROR OF ESTIMATE = 0.11

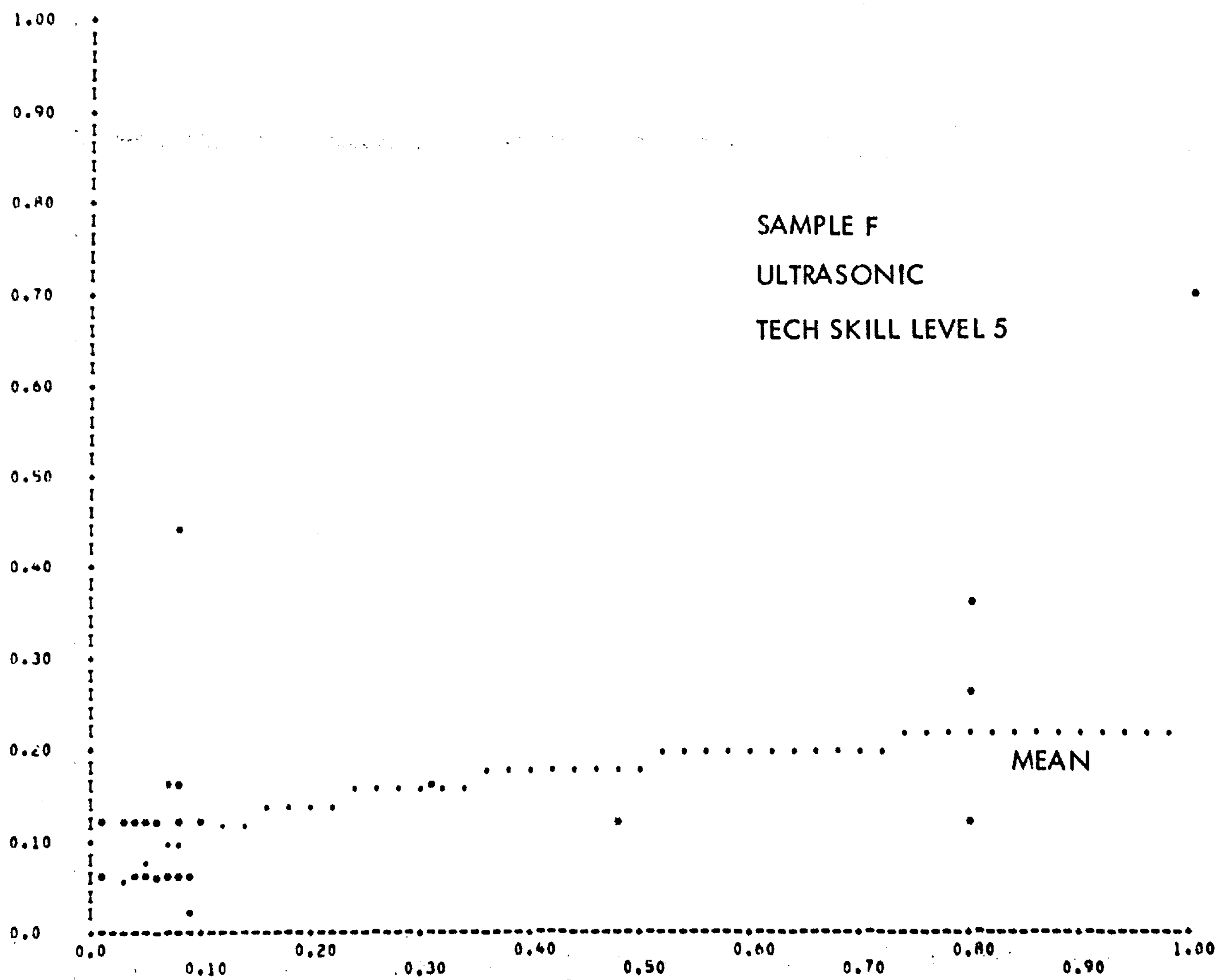


Figure 11-90

SAMPLE: F

METHOD: UT

NO OF INSPECTORS: 5

NO OF FLAWS: 34

INPUT RECORD: 05 F UT 1 7 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).

TECH SKILL LEVEL 7 SAMPLE F (UT)

EQUATION Y=A*X**B A = 1.08061 B = 1.132899

COEFFICIENT OF CORRELATION = 0.994 COEFFICIENT OF DETERMINATION = 0.833

STANDARD ERROR OF ESTIMATE = 0.18

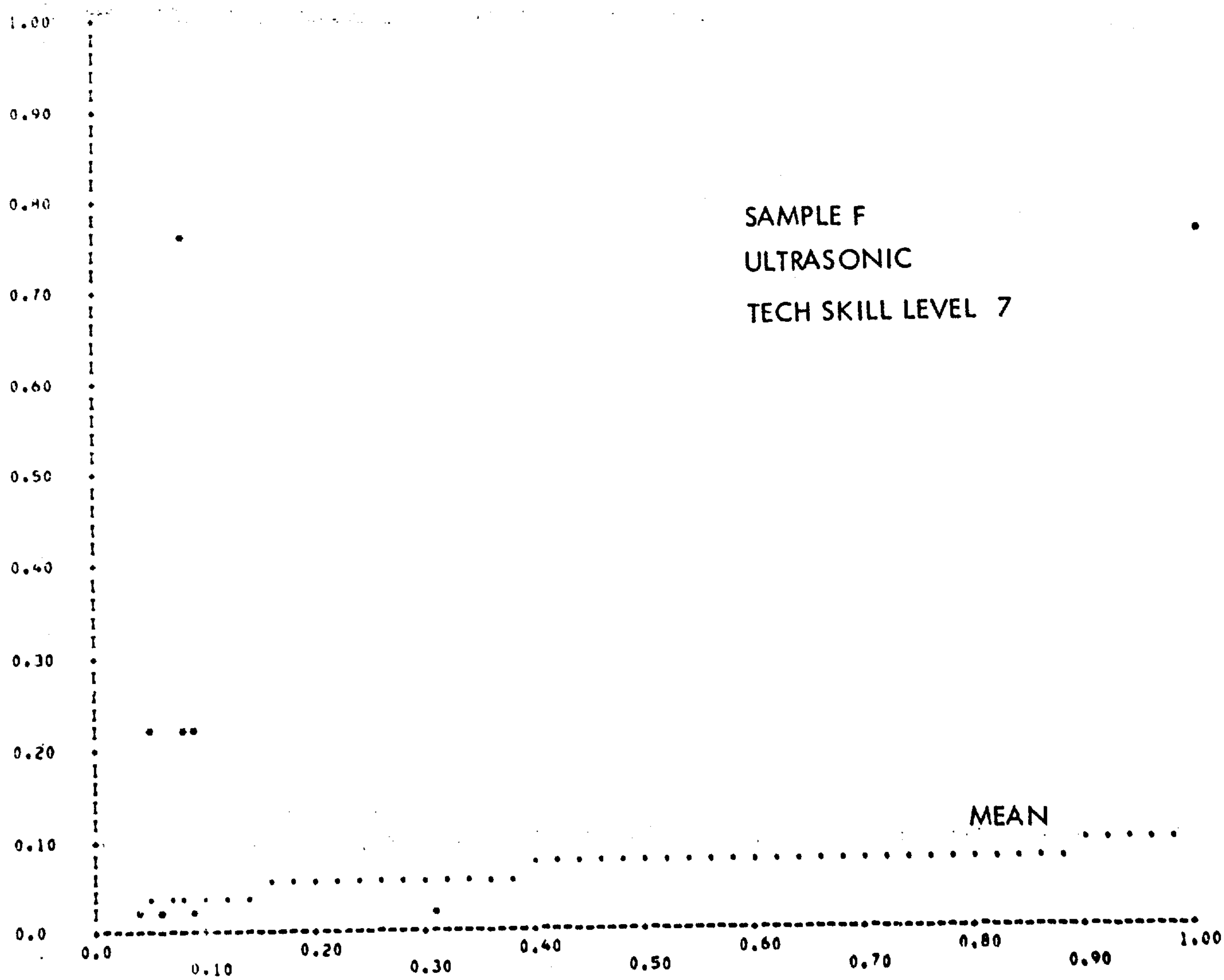


Figure 11-91

SAMPLE: F

METHOD: UT

NO OF INSPECTORS: 5

NO OF FLAWS: 34

INPUT RECORD: 38 F UT 1 150 250 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).

TECH UNDER 25YRS AGE SAMPLE F (UT)

EQUATION Y=A*X**B A = 0.674047 B = 1.261573

COEFFICIENT OF CORRELATION = 0.995 COEFFICIENT OF DETERMINATION = 0.871

STANDARD ERROR OF ESTIMATE = 0.17

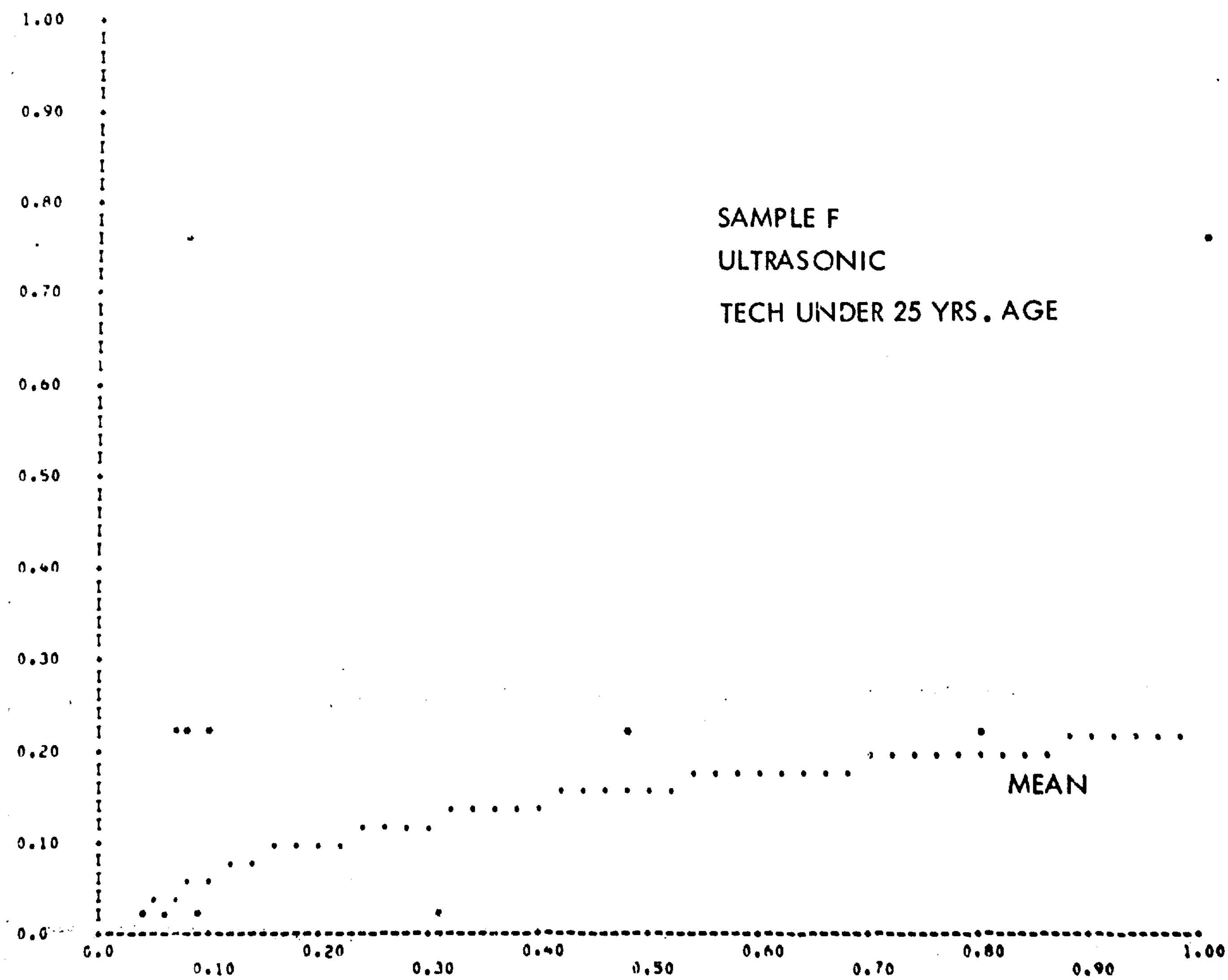


Figure 11-92

SAMPLE: F

METHOD: UT

NO OF INSPECTORS: 10

NO OF FLAWS: 34

INPUT RECORD: 08 F UT 1 400 990 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).

TECH OVER 40YRS AGE SAMPLE F (UT)

EQUATION Y=A*X**B A = 0.892482 B = 1.152792

COEFFICIENT OF CORRELATION - 0.949 COEFFICIENT OF DETERMINATION - 0.900

STANDARD ERROR OF ESTIMATE - 0.12

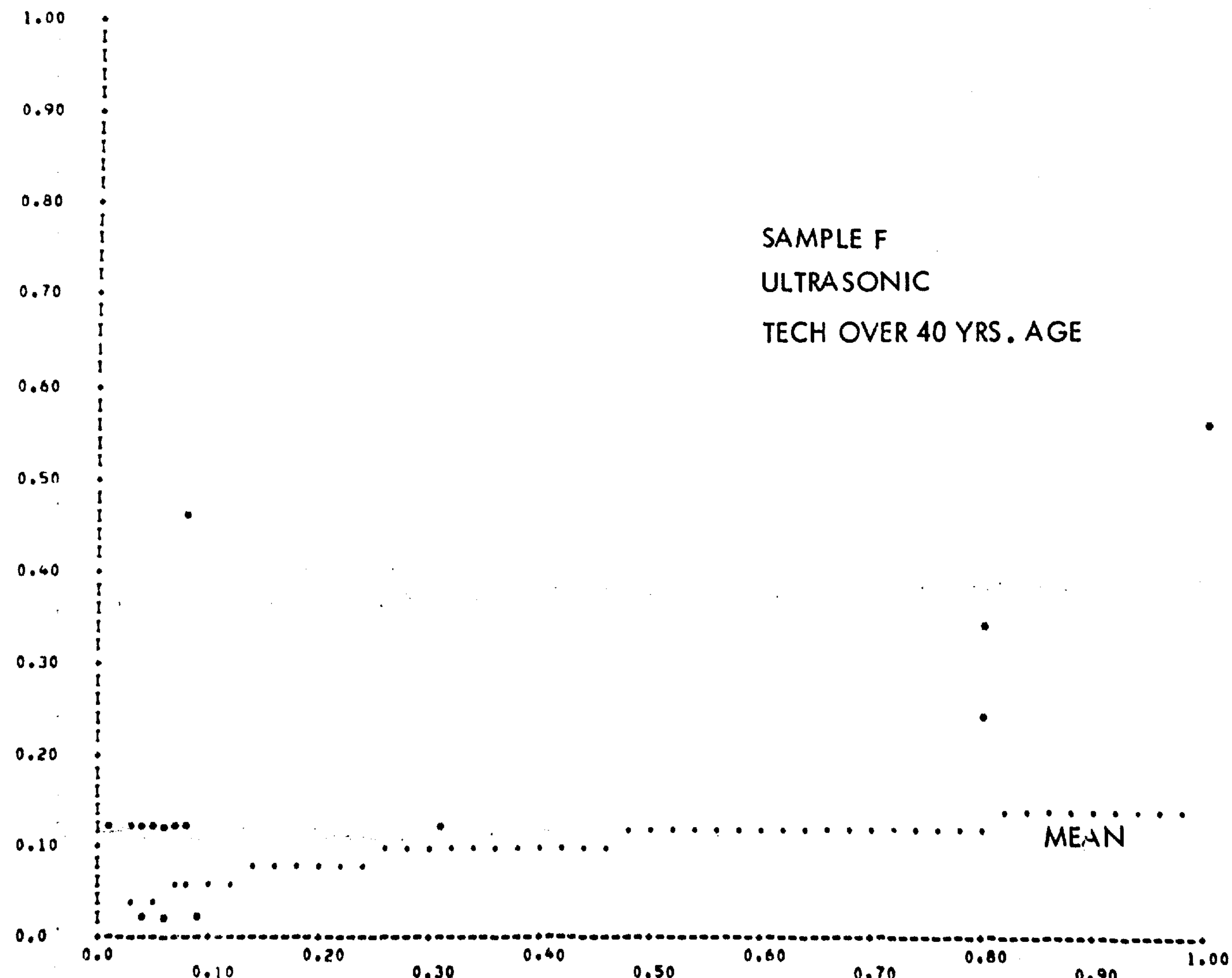


Figure 11-93

SAMPLE: F

METHOD: UT

NO OF INSPECTORS: 26

NO OF FLAWS: 34

INPUT RECORD: 09 F UT 1 011 099 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).

TECH OVER 10 YRS EXPER. SAMPLE F (UT)

EQUATION Y=A*X**B A = 0.659609 B = 1.191682

COEFFICIENT OF CORRELATION = 0.957 COEFFICIENT OF DETERMINATION = 0.931

STANDARD ERROR OF ESTIMATE = 0.12

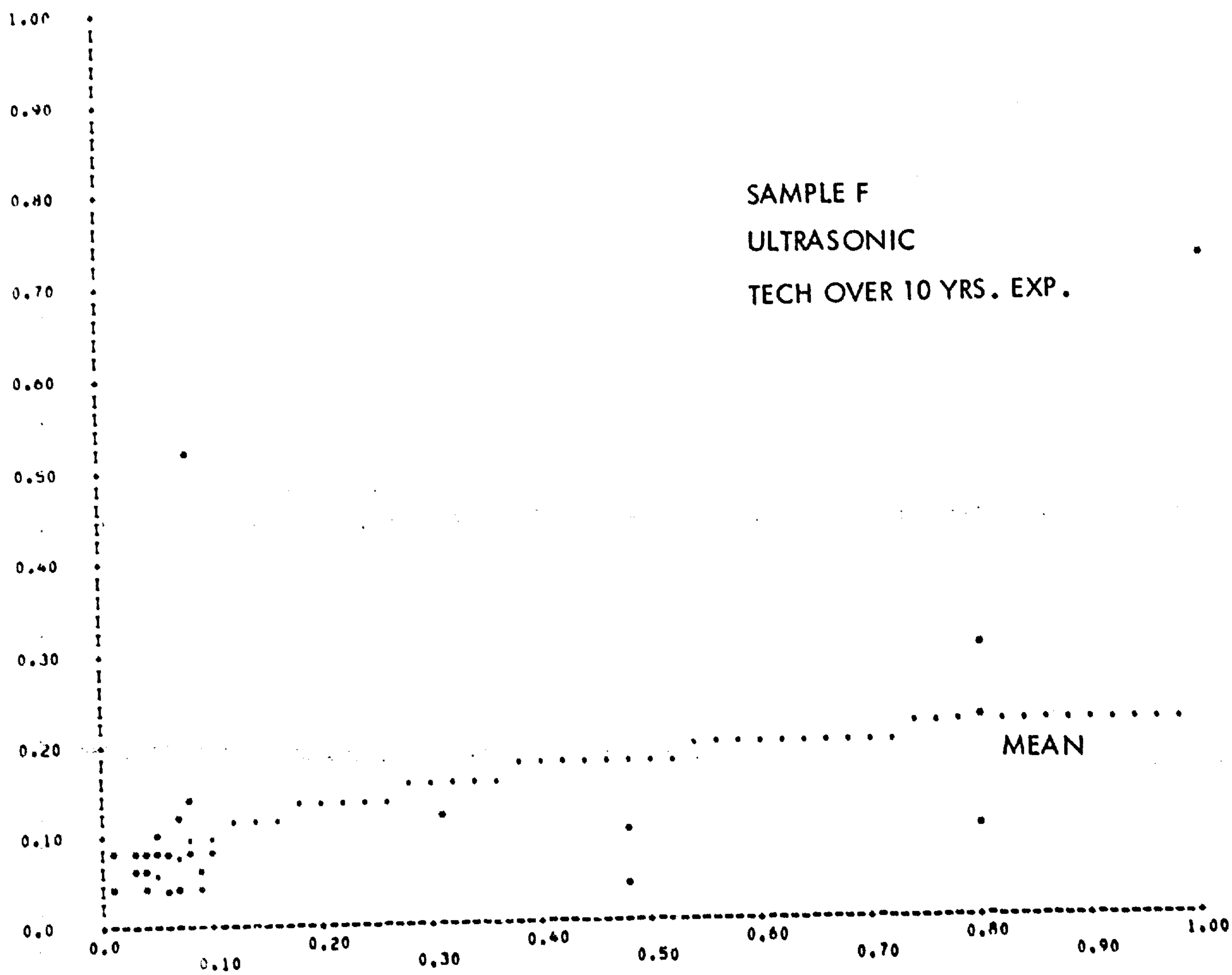


Figure 11-94

SAMPLE: F

METHOD: UT

NO OF INSPECTORS: 13

NO OF FLAWS: 34

INPUT RECORD: 10 F UT 1 000 200 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).

TECH 0-200HRS NDI TRNG SAMPLE F (UT)

EQUATION Y=A*X**B A = 0.738740 B = 1.111076

COEFFICIENT OF CORRELATION = 0.896 COEFFICIENT OF DETERMINATION = 0.912

STANDARD ERROR OF ESTIMATE = 0.11

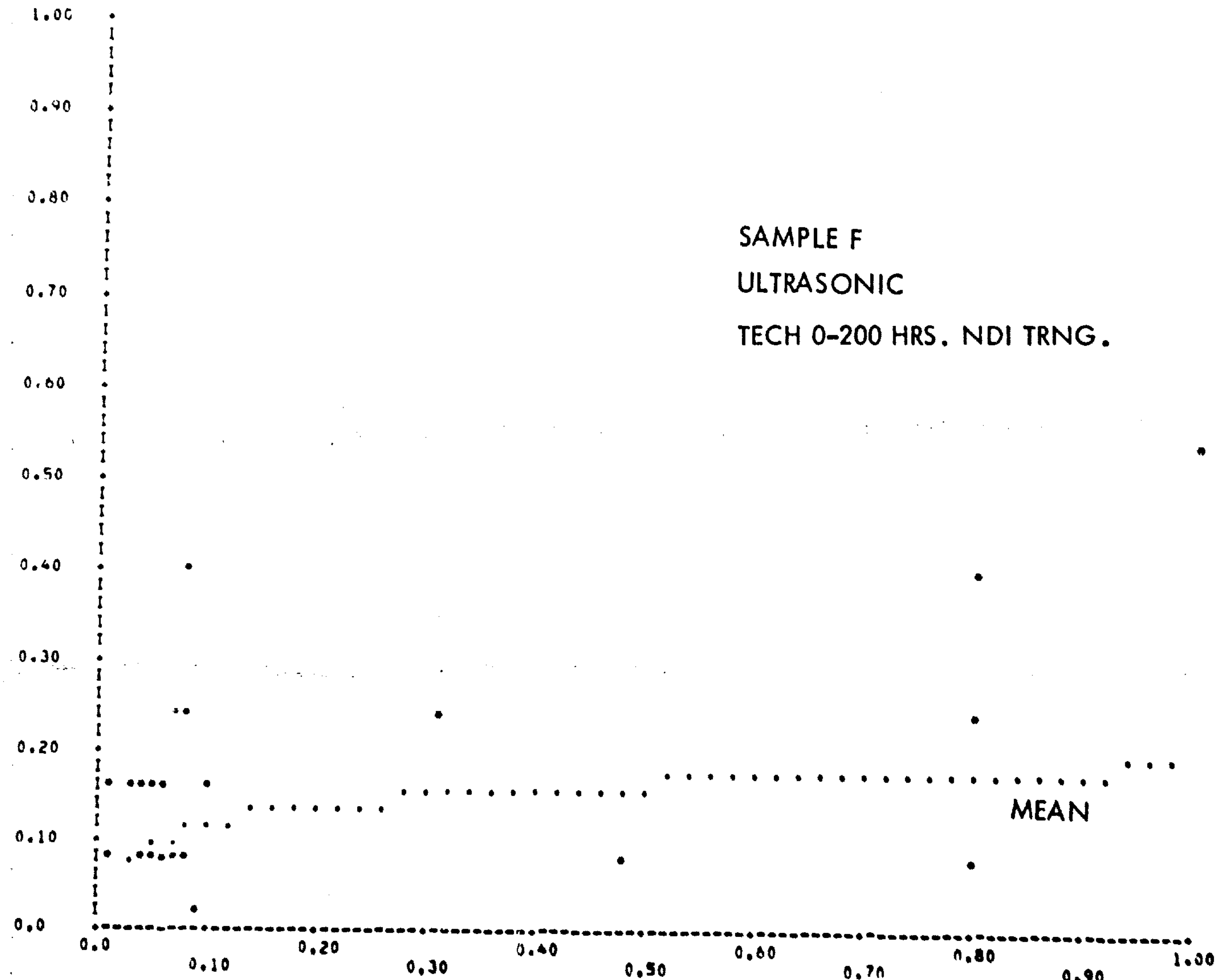


Figure 11-95

SAMPLE: F

METHOD: UT

NO OF INSPECTORS: 4

NO OF FLAWS: 34

INPUT RECORD: 10 F UT 1 500 999 95 10

CONFIDENCE LEVEL: .95

X AXIS IS FLAW RADIAL LENGTH (INCHES).

TECH 500+ HRS NDI TRNG SAMPLE F (UT)

EQUATION Y=A*X**B A = 0.186735 B = 1.616397

COEFFICIENT OF CORRELATION - 0.998 COEFFICIENT OF DETERMINATION - 0.446

STANDARD ERROR OF ESTIMATE - 0.26

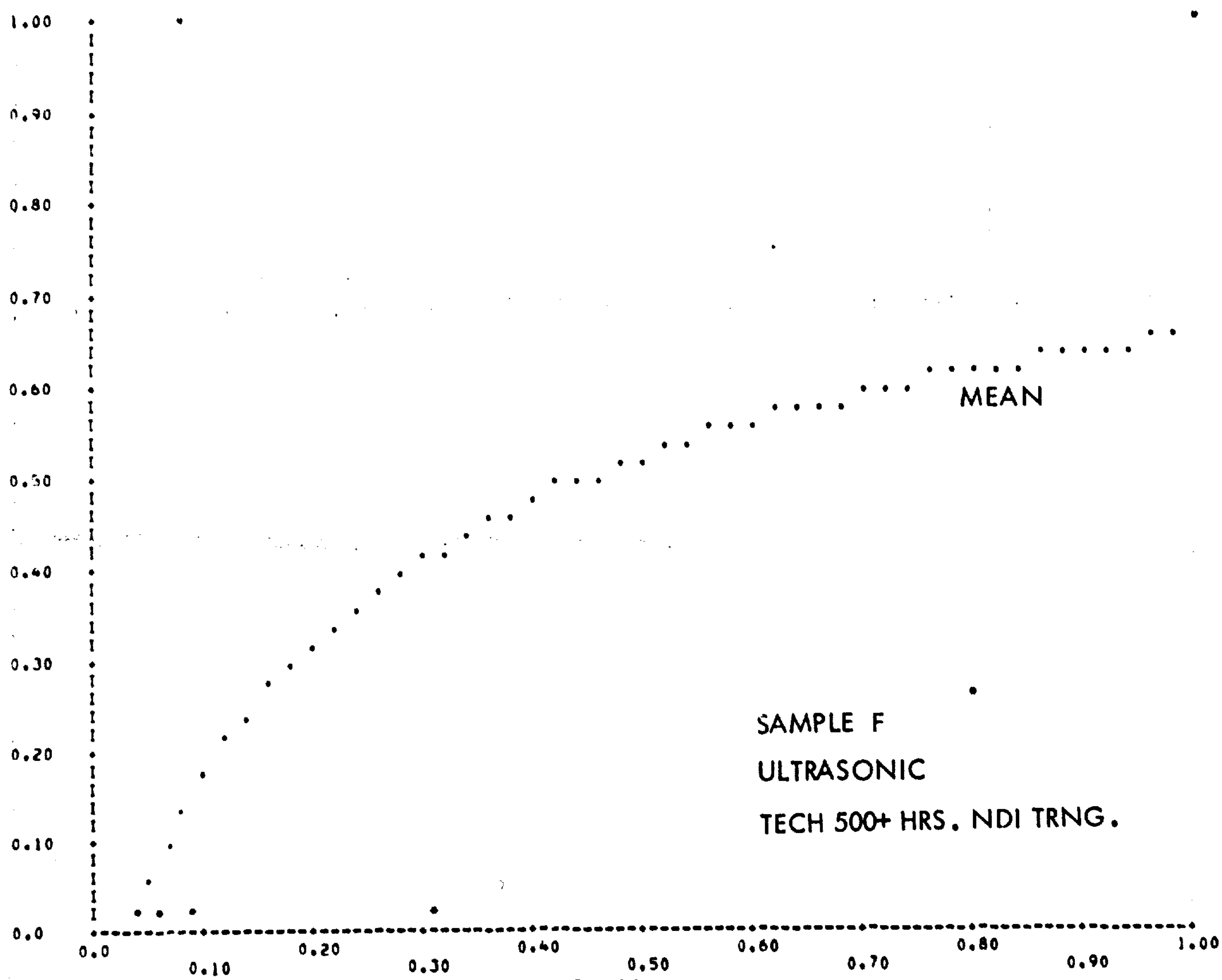


Figure 11-96

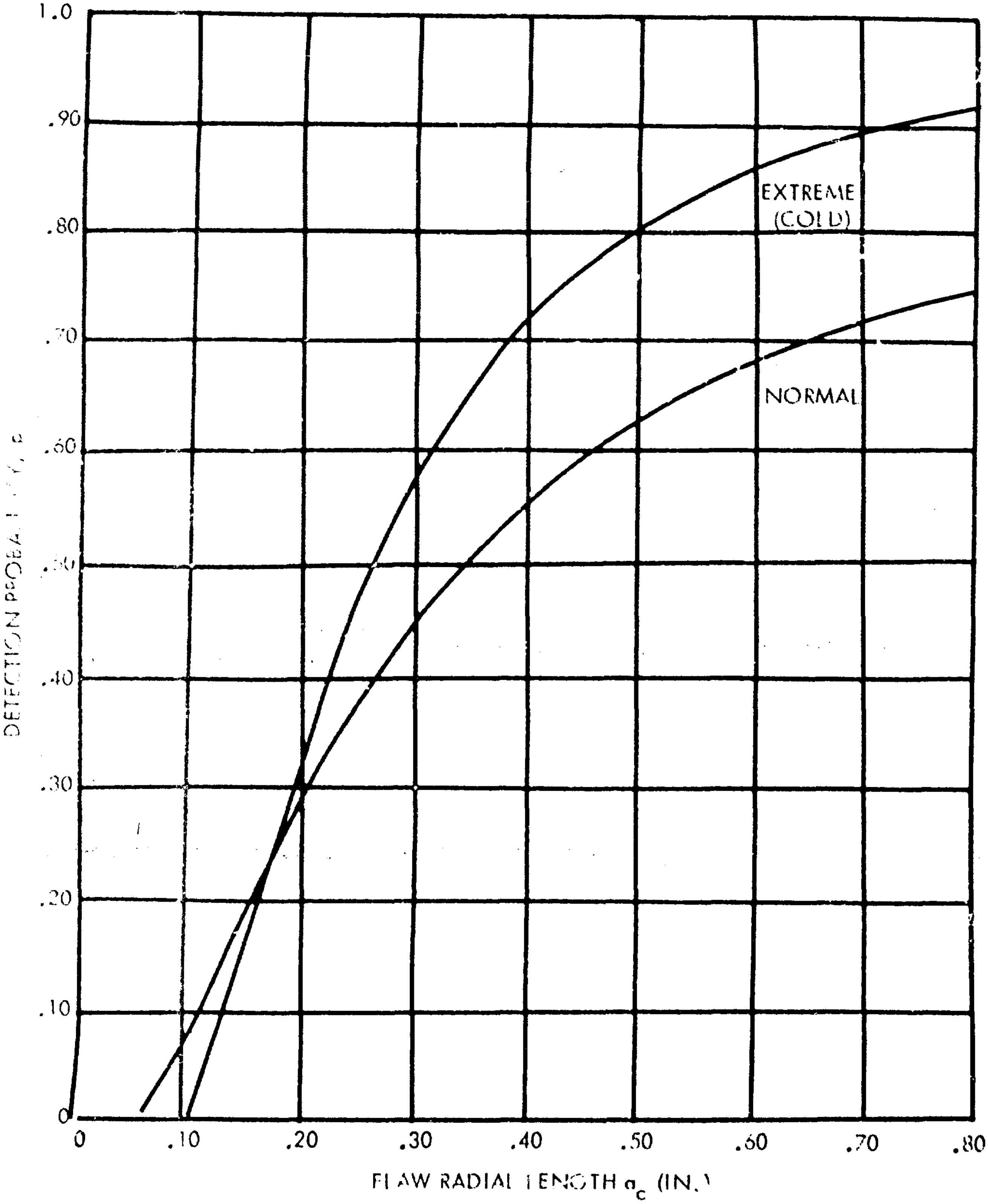


Figure 11-97. Probability of Detection Versus Fatigue Crack Radial Length, Radiographic NDI for Cracks around Countersunk Fasteners, Skin and Stringer Wing Segments, Sample B - for Normal and Extreme Outdoor Weather Conditions

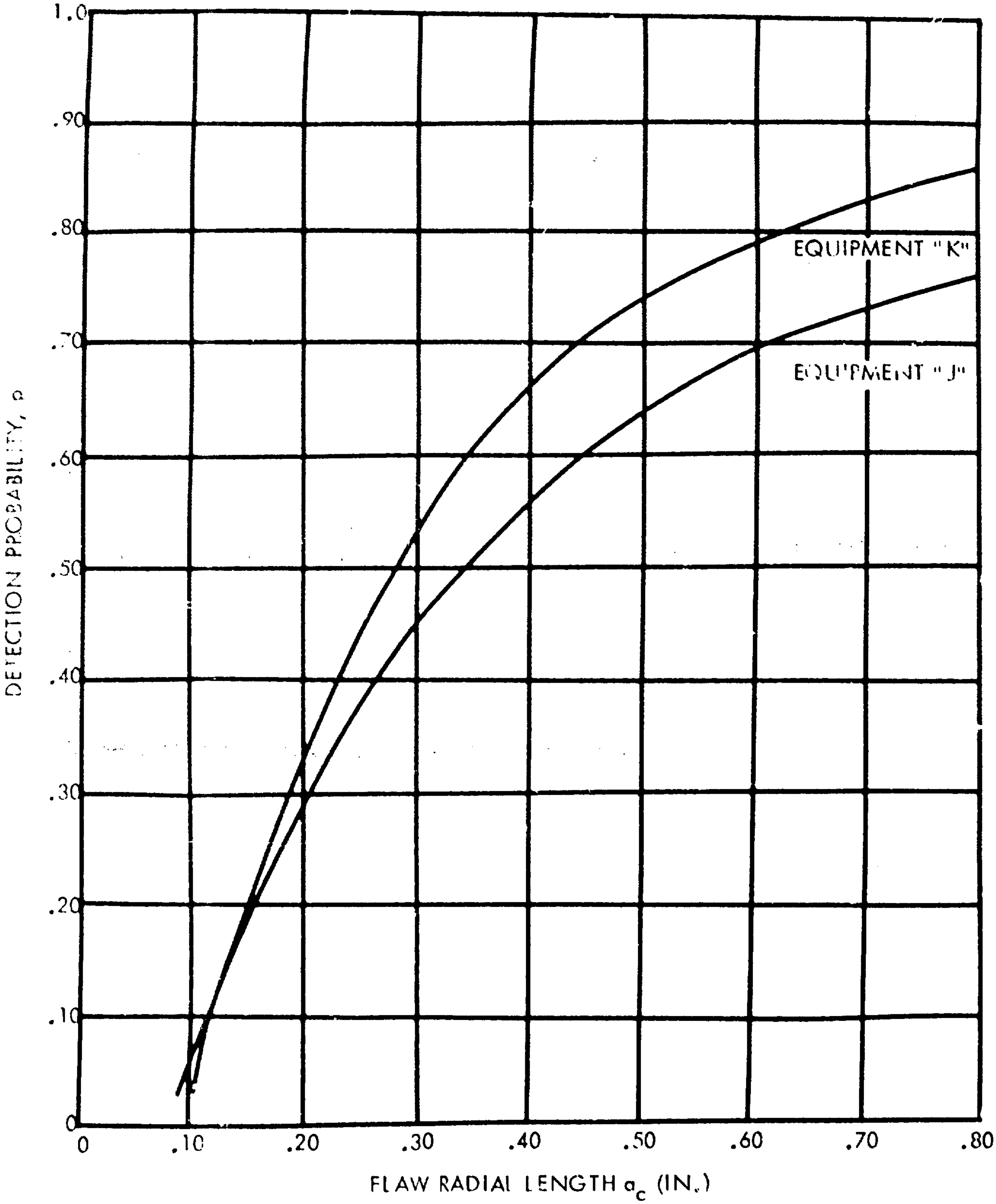


Figure 11-98. Probability of Detection Versus Fatigue Crack Radial Length, Ultrasonic Shear Wave Scans Around Countersunk Fasteners, Skin and Stringer Wing Assembly, Sample A - for Ultrasonic Instruments of Two Different Manufacturers

SECTION XII. CONCLUSIONS AND RECOMMENDATIONS

This program was designed to measure the overall performance of nondestructive inspections currently employed by the United States Air Force in maintenance of aircraft structure both at field and depot locations. The primary intent was to quantitatively measure the reliability of NDI to detect service induced cracks in aircraft structure. There was also an opportunity during the program to observe and record data on many variables associated with the NDI process, such as human factors, environment, and equipment operation.

The overall results of initial analyses of the data are presented graphically in Section X, while more detailed analyses with regard to selected variable are presented in Section XI. This Section, XII, provides a commentary on the results of the analyses and observations made in the data acquisition phase of the program. Because of the exceptionally large amount of data acquired during the course of the program and the potential impact that it will have on the technology, additional analyses and data treatments outside the scope of this program may extend the conclusions and recommendations presented.

The current program conclusions are first discussed in terms of observations of the data within the context of current practices of general nondestructive inspection technology within the Air Force today. Secondly, conclusions of a specific nature are discussed in terms of the data provided in Section X, which depicts overall findings derived from the NDI method/structure combinations employed in this program and each of the more detailed analysis categories developed in Section XI. Then a number of recommendations based on both data analyses and observations made in the course of data acquisition are provided.

GENERAL CONCLUSIONS

The overall reliability of nondestructive inspections currently used by the Air Force and evaluated in this program, falls below that which has been assumed or generally desired. The measured probabilities of detecting fatigue cracks in built-up aircraft structure using typical maintenance inspection techniques and procedures are not as high as most designers and structural engineers would prefer and certainly not as good as those responsible for aircraft maintenance and safety would expect.* The results, however, are not surprising to many of those closely associated with applications of nondestructive inspections and the data substantiates many opinions previously expressed regarding current NDI reliability.

*Military specification, MIL-A-83444 (USAF), "Airplane Damage Tolerance Requirements", states that in-service inspections (at a depot or base level) are assumed capable of detecting cracks of 0.25 inch uncovered length, emanating from one side of a hole, if the material thickness is equal to or less than 0.25 inch. Similarly, a quarter-circular corner crack of 0.25 inch uncovered length applies for material thicknesses greater than 0.25 inch.

Of foremost importance is the realization that the previously established 90-95 percent reliability criteria (90 percent probability of detection with a 95 percent confidence bound) cannot be attained with normal inspection methods. With the exception of fluorescent penetrant inspection, the NDI techniques employed in the program demonstrated considerable difficulty achieving a 50 percent probability of detection for a 1/2-inch crack size with a 95 percent confidence level. It should be pointed out, however, that all conclusions contained in this report are based on the data obtained during the NDI Reliability program which used the NDI techniques and equipment currently available at the Air Force installations visited.

The state-of-the-art is constantly changing in NDI technology. Inspection reliability improvements resulting from recent refinements in NDI methods, presently undergoing service evaluation were not included in this study. There was a limited opportunity to evaluate the effectiveness of semi-automatic eddy current and ultrasonic equipment, beginning at the thirteenth base visit. Unfortunately, due to the late incorporation of semi-automated equipment into the program, the data quantity restricted determination of a reasonable confidence level for this equipment, but the mean crack detection levels obtained from using this type of equipment indicate that 90-95 percent reliability criteria may be possible at crack sizes considerably smaller than 1/2 inch.

The average capability among both field and depot NDI shops is, with one exception, uniform and predictable. This aspect of uniformity is a strong point which can be used to advantage if changes are incorporated Air Force-wide into the NDI system. A measure of the effect resulting from a change at a small sample of locations should be indicative of what would be found if the same measure were applied to a large sample. Another strong point is the performance observed at the one exceptional location. The distinctly higher flaw detection success exhibited at this facility, especially with eddy current bolt-hole NDI, as shown in Figures 10-14 and 10-15, has demonstrated that much better performance levels than those generally demonstrated are possible. Since all participants used the same structure samples, procedures and types of equipment which operated within acceptable performance characteristics, it must be concluded that large differences are attributed to individual proficiency. This one facility, the second depot visited in the data acquisition phase, has conducted NDI operations as a specialty, has been selective in obtaining skilled personnel and has performed a type of personnel certification which was effective. Those attributes can serve as a model in plans for Air Force-wide efforts to upgrade NDI performance.

Outside of the differences found between standard NDI techniques and the recently introduced semi-automatic techniques, the major variation in inspection results was found among the individual technicians themselves. There was an extremely wide variation exhibited between individual technicians as evidenced by the curves plotted for only the upper 10 percent of technicians contrasted to the mean curves for all technicians which is illustrated in Section X.

There were no significant differences (excepting the one depot previously mentioned) found between individual installations, between individual Commands, or between field installations and depots. Neither was there a significant difference observed between technicians using different manufacturer's equipment. The primary source of variance between the

individual technicians was in the human factors area, which remains to be further investigated. The specific variables of formal education, age, classification skill level, NDI experience, and NDI training were each analyzed and proved to have only minimal influence on resulting NDI performance.

Another human factors aspect which has been observed but has not been treated in this program is the false call level. There is not yet a generally agreed upon method for analyzing the impact of these false calls on NDI reliability. The raw data presented in Section V show extremely high false counts for some technicians performing radiographic NDI, for example. The success scores for these individuals are therefore suspect because a number of finds can be attributed to pure chance. Fortunately, the instances of extremely high false call levels were not numerous enough to make the total data picture suspect.

SPECIFIC CONCLUSIONS

Percentile Comparisons

One of the most significant findings in the program is that there are considerable differences in the NDI proficiencies of individual technicians. Some technicians are very good and some are very poor at detecting flaws in structure and/or interpreting test results. After considering the relatively weak effects of technician age, skill level, formal education, NDI training and NDI experience, such vast differences among individuals must be attributed to inherent "human factors". When the technicians are divided into performance percentile groups, the wide range in variations is revealed. A pronounced difference in performance is observed in comparison of the results of all technicians with the results of the upper ten percent of technicians. This was done for POD plots for Samples "E" and "F" using eddy current bolt-hole NDI (see Figures 10-9 and 10-11) and for Sample "A" using ultrasonic shear wave NDI (see Figure 10-2). In all cases, the curves show that an improvement in detection reliability of about 0.5 (on a scale of 0.0 to 1.0) can be gained if the upper ten percentile performers are used for the inspection. This is particularly true in the shorter flaw length region where the total (mean) group exhibits very low probabilities of detection and the upper ten percent group performs with substantially greater success.

Depot Performance

There are no generally distinct contrasts between depot performance and the overall means among most structure types and NDI methods, except for two cases. As a group, the depots performed the radiographic inspections at a level of performance below the overall mean for all installations (see Figures 11-34 and 11-35). Hence, distinctly low radiographic performance is attributed to the depots. On the other hand, depot performance in eddy current bolt-hole inspection was distinctly above the overall mean (see Figures 11-63, 11-64, 11-75 and 11-77); but these high results can be attributed to the outstanding performance of one depot, which pushed the group results above the mean. Overall, there appears to be no significant difference between depot and field NDI performance.

Skill Level

Comparisons made with respect to the Air Force skill levels of technicians have inconsistent results. The higher skill levels did not necessarily turn in the best performance. Variations occurred with respect to NDI method and structure type. Pronounced improvements with increasing skill level - among the Air Force 3, 5 and 7 skill levels - were apparent on structure Sample "E" with eddy current bolt-hole (ECBH) NDI (see Figures 11-65, 11-66, and 11-67). This trend did not hold true, however, for ECBH NDI on Sample "F", in which case the level 5's outperformed the level 7's (see Figures 11-78 and 11-79). The level 7's did perform better than level 5's using radiography on Sample "B" (see Figures 11-36 and 11-37), but fell below the level 5's when using ultrasonic shear wave on Sample "A" (see Figures 11-15 and 11-16). Generally speaking, the skill level impact on overall performance appears minimal and the only conclusion that can be drawn from the data is that technician proficiency in crack detection ability does not correlate with Air Force skill level.

Formal Education

The cases dealing with no high school education, as compared with those for all technicians, show that absence of a full high school education is not detrimental to performance. This observation is evident, for example, for eddy current bolt-hole NDI on both "E" and "F" structure samples (see Figures 11-63, 11-68, 11-75 and 11-80).

Age Differences

The effect of technician age (i.e., "maturity" and physical accuity) on NDI performance was investigated by analyzing the results of two age groups. The performance of technicians under 25 years of age were contrasted with the performances of technicians over 40 years of age. The results of this comparison were again mixed. The older group performed better than the younger group using the ultrasonic technique on Sample "A" (see Figures 11-17 and 11-18), and the eddy current bolt-hole technique on Samples "E" and "F" (see Figures 11-69, 11-70, 11-81 and 11-82). In contrast, the younger group performed more reliably using the ultrasonic technique on Sample "F" (see Figures 11-92 and 11-93) and the radiographic technique on Sample "B" (see Figure 11-38). Since there is no apparent reason to assign age attributes to the program samples or to the techniques, the results provide no basis for predicting performance based on age.

Years of NDI Experience

As with age, two experience groups were compared. The performance of technicians having less than three years NDI experience was compared with the performance of technicians having more than ten years experience. Since the duration of experience is loosely related to age, it is not possible to entirely isolate the effects of these separate variables. Nevertheless, a comparison of the two experience groups showed no substantial difference in performance. Only on the plots for Samples "E" and "F" for eddy current bolt-hole NDI (see Figures 11-72, 11-73, 11-83 and 11-84) was there significant differences for the experience evaluations, and these differences occurred only in the extrapolated regions of the plots. The point estimates are very similar. Hence, no generally predictable trend was evident in the comparisons for length of NDI experience.

NDI Training

The hours of formal NDI training, as reported by the technicians, were examined for effect on perfomance by contrasting those with under 200 hours to those having over 500 hours. There is some indication that an inverse relationship exists, i.e., those with more formal training do not perform as well as those with less. This does not mean that additional training would degrade performance, but it does indicate that additional formal training of the type reported would not automatically yield improved proficiency. For example, a pronounced inverse relation between performance and training level appears in the case of ultrasonic shear wave NDI on Sample "A" (see Figures 11-20 and 11-21), yet the opposite result appears for ultrasonic shear wave NDI on Sample "C" (see Figures 11-61 and 11-62). These contradictory examples indicate that one or more additional variables have influenced the results and that further analyses will be necessary to gain a clear picture of NDI training effects.

RECOMMENDATIONS

Near-Term NDI Reliability Improvements

The primary source of the variance in the data collected and the main cause of failure to detect flaws is attributed to the human factor element in the NDI process. There is a need to concentrate on a practical method to evaluate the proficiency of the NDI technician as well as an increased evaluation, skill development and motivation of the NDI technician. Practical NDI examinations should be periodically administered to technicians and their performance ratings made available to them. Opportunities for periodic re-examination and flaw detection practice on hardware would be highly desirable. Mandatory review of ratings by supervision and management would provide avenues for positive motivation.

Other sources of motivation can be implemented on a near-term basis. For example, the NDI decals distributed during the field data collection part of the program were of significant interest to the NDI technicians. Many expressed a desire to have a uniform patch similar to the decal. Therefore, Air Force approval for the use of such a uniform patch by military NDI personnel should be sought.

Proficiency Determinations

The commonly assumed indicators of NDI proficiency such as technician skill level, years of experience, maturity in terms of age, extent of formal education, and hours of formal NDI training do not provide a true indication of flaw detection proficiency. True proficiency of a technician must be evaluated by methods which have a proven and consistent relationship with actual flaw detection capabilities. Practical examinations, administered with actual flaws in hardware, should be developed for such proficiency determinations. Standards of performance need to be established with the norms set to attainable goals defined from experience.

Certification

Presently, the formal NDI training to attain a skill level is performed at Chanute Air Force Base, where the technician attends a course for the level sought. The individual then remains at that level until, through experience and study, he or she is qualified to attend the training course for the next higher level.

NDI personnel at the Logistics Centers are trained in NDI in accordance with the requirements established at each of the five centers. In some Logistics Centers, NDI is a part-time activity and not the primary job, while in other centers it is a full-time job. It is recommended that the Logistics Centers centralize NDI activities and make NDI a full-time certified occupation where this is not already established.

It is also recommended that a standard certification-recertification program be established through the administration of practical examinations at all bases and depots. Kits or certification packages, composed of hardware with cataloged flaws, detailed NDI procedures and complete instructions for the test administration, could be developed. A certification body would manage the scheduling, grading and reporting functions, but each base or depot could implement the testing. A routine would also have to be established to reassign noncertifiable personnel.

Training

Formal training programs vary in content and quality in part due to personnel changes, variable funding, changes in instruction courses, and variations in the use of training aids. Informal training (on-the-job training) suffers an even wider range of variation in quality. A comprehensive evaluation of all training functions for NDI should be considered. Of particular importance, the Chanute Air Force Base NDI course should be given first attention. To this end, it is recommended that a Training Review Committee be established to evaluate that training facility. This committee should include persons knowledgable in education, human factors, psychology, as well as current and future AF NDI requirements. This group should conduct evaluations of the content of the overall training program and the methods used for its delivery; plus evaluations of Chanute Air Force Base NDI training personnel, equipment, training facilities and training aids. When these evaluations are done, a complete report of findings with recommendations should be made by the Committee to the Air Force Training Command for review and implementation.

Logistics Center NDI Training: The training of NDI personnel at the Air Force Logistics Centers is a local in-house operation, supplemented by commercial courses such as Magnaflux, General Dynamics, and Eastman Kodak. All NDI personnel of the Logistics Centers are civilian employees and personnel turnover is much lower than at military field installations; therefore, no separate full time training facility is justified.

Personnel Screening Program: It is recommended that a study be conducted to develop a personnel screening program for selection of NDI personnel. The intent of this program would be to identify those candidates who are compatible with the occupation and to eliminate from the NDI career field, those persons not suited by intelligence, temperament, or dexterity for NDI type work.

The screening program, during its development, could be evaluated by first testing a group of NDI technicians to determine their relative inspection abilities, and then subjecting these technicians to the screening program to determine if the program correctly differentiates between the good and bad inspectors. After the program is found to be suitably accurate, its successful completion by potential NDI technicians should be established as a requirement for entry into NDI training. For a period of time, personnel who entered the NDI field via this route should be evaluated to determine if they do indeed turn out to be proficient inspection personnel.

On-the-Job-Training: The final training recommendation concerns on-the-job training (OJT). It is recommended that a standardized OJT program be developed and instituted Air Force wide. Standard training kits with training manual should be developed and distributed to each Air Force Base. These kits would include actual fatigue cracked structure typical of that to be found in service (at present there are none available for this purpose). These specimens should contain a spectrum of flaw sizes and should include structure to be inspected by ultrasonics, eddy current, surface probe, eddy current bolt-hole probe, penetrant, x-ray, and magnetic particle.

Equipment

The state-of-the-art equipment used in both the pre-data acquisition trials and in the data acquisition itself, was inherently capable of response to the majority of flaws in the structure samples. In some cases, however; notably on Sample "F" with ultrasonic NDI, it was not possible to routinely obtain responses from all the flaws. The question then remains: why is a flaw missed if the process is capable of detection? One important answer is: the equipment and/or process does not sufficiently alert the operator when a flaw response is present. There are potential solutions to this problem within the realm of equipment design improvements. Several of these are to: (a) improve the signal-to-noise ratio in both detection and readout functions, (b) promote operator vigilence through enhanced stimuli to sensual perception, (c) channel the operator's attention to flaw indications, (d) provide positive assurances that the equipment is performing its intended functions, and (e) automatically program and control those functions which are susceptible to human error.

Each of these potential equipment improvements is within the scope of today's technology. Programs to develop improved versions of NDI equipment and processes should include guidance from the technician/user, including engineering specialists and the personnel responsible for the day-to-day NDI operations. Full advantage should be taken from the advent of microprocessors and newly emerging electronic devices which provide a number of powerful, complex operations for signal processing, instrument readout and process control. In all cases, any "improved" version of equipment should demonstrate its flaw detection reliability under realistic conditions. Improved resolution, sensitivity and flaw characterization features do not automatically imply superior flaw detection reliability. The process of detection is uniquely different from the interrogation of the flaw itself. In some cases, the function of flaw searching should be separated from the activity of flaw interrogation. Therefore, different equipment designs or approaches may be necessary to optimize each.

Interdisciplinary Analyses

Information that has been derived from this program is applicable to planning inspection intervals, optimizing NDI operations and the formulation of structural failure risk analyses. A number of NDI options should be explored through various treatments of the raw data stored by computer as described in Section VIII, Data Storage and Retrieval. Various combinations of redundant NDI with the same method and mixes of different methods should be examined for cumulative detection probabilities. The known detection levels for given flaw sizes should be integrated into fracture and fatigue models to exercise inspection interval options. Comprehensive structural risk analyses are also possible with a knowledge of flaw detectability. Information concerning initial flaw size distributions in new structure, flaw growth rates and detection probabilities provides a basis for predicting failure probabilities under service conditions. Heretofore, risk analyses employed only assumptions for in-service flaw detectability. With the data now available from this program, these risk analyses should be updated for more accurate predictions.

Workshop Findings

A number of recommendations concerning NDI reliability improvements have been made by the eight Task Groups who reviewed data from this program at a Government/Industry Workshop on NDI Reliability held in Houston, Texas, 2-4 August 1978. The complete report on this activity is provided in the publication entitled "Workshop Proceedings - Government/Industry Workshop on NDI Reliability," Report No. SA-ALC/MME 76-6-38-2. The major problem areas which were addressed are as follows:

1. Personnel
2. Training
3. Certification
4. Operations (Management)
5. Equipment
6. Reliability Measurement/Modeling
7. Fracture Mechanics/NDE Interrelationships
8. Data Analysis

A summary of Workshop recommendations for each problem area is provided below:

Personnel

Individuals should be selected on the basis of identified traits which are necessary for high proficiency and motivation. Rewards and information feedback provisions should be implemented to promote excellence.

Training

Classroom and practical training aimed at multiskilled NDI capabilities should be conducted in two phases of professional development. The first phase should have 45 percent class time and 55 percent practical "hands-on" instruction. The second phase should have 35 percent class time and 65 percent "hands-on". Both training phases should be conducted at a centralized facility for uniformity.

Certification

A formal certification of personnel by examination, which consists of both written and practical segments would, without question, improve reliability. It should definitely be required of all personnel who perform NDI on aircraft or aircraft components.

Operations (Management)

NDI should organizationally report directly to the chief of maintenance and personnel should be assigned to full time NDI. Depots should be given the authority to monitor field operations, provide well defined NDI procedures as Technical Orders, assure the availability of proper equipment for field use and provide training assistance to the field.

Equipment

Improvements in equipment should be sought through automation and the use of digital processors for control and data treatment. Permanent records and visual displays are desirable and necessary adjuncts to maintaining vigilence in detection. Combined flaw search and characterization attributes would be good to have in a single instrument.

Reliability Measurement/Modeling

The "windows" for new studies deal with the signal-to-noise considerations in, human factors, equipment, and validation of models. Attention should be given to the man/machine interface, the physical/mental attributes, equipment output stimulus level and patterns and modeling transfer functions to account for test object shape.

Fracture Mechanics/NDI Interrelationships

The trade-offs between frequency of inspection and redundant NDI applications should be examined for their impact on reliability. Technical Order NDI procedures tailored to fracture critical parts should be developed for any new aircraft or major assembly. Risk analysis which uses NDI reliability data should be examined.

Data Analysis

Further examination of existing data should be made before any additional data are acquired. New programs should define the questions the data are to answer, define the analysis model, define the experiment to elucidate cause and effect and the data should be amenable to different analysis methods.

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APPENDIX A

SELF INTRODUCTION FOR AUTOMATED EDDY CURRENT SCANNING SYSTEM

and

OPERATIONAL SUPPLEMENT NO. 1 - TECHNICAL MANUAL NONDESTRUCTIVE INSPECTION RELIABILITY PROGRAM

SELF INTRODUCTION FOR AUTOMATED EDDY CURRENT SCANNING SYSTEM

NOTE

The following instructions are to be used for training personnel in the use of the Gulton FD-100 Automatic Eddy Current Scanning System. Any questions concerning instrument settings, calibration, operation or interpretation should be directed to the attending Lockheed Georgia Company Engineer.

Equipment:

(1) Crack Detector, Gulton FD-100

Automatic Eddy Current Scanning System **(figure 1)**

(2) Probe, Bolt Hole, 3/16-inch, 1/4-inch, and 5/16-inch, diameter P/N L 102748-1, -3, -5, or equivalent

(3) Calibration Standards SS-1 and CW-1 (See figure 2.)

(4) Practice Specimens SSB-1 (figure 3) and CWB-1 (figure 4)

Access: The fasteners have been removed from holes that are to be used in this program.

Preparation of Part: The holes have been cleaned; therefore, no additional cleaning should be required. However, after repeated inspections the accumulations from probe wear deposits should be removed with solvent and a brush.

Instrument Setting/Calibration: The following general instrument set up and calibration instructions are to be used for training purposes using the Gulton automated eddy current scanning system and the practice specimens SSB-1 and CWB-1.

(1) Open the FD-100 instrument case and remove all cables and the scanner head from the storage compartment.

(2) Connect the scanner head cable to the MOTOR connector on the FS-100 instrument.

(3) Connect the scanner head RF signal cable to the SIGNAL connector on the FD-100 instrument.

(4) Connect the three (3) wire power cable to the FD-100 and plug into a 60 Hz 115 VAC grounded outlet.

WARNING

> The FD-100 system uses a safety grounded, three (3) wire AC power input. DO NOT ATTEMPT TO CHEAT OR DEFEAT THE BUILT-IN SAFETY GROUND. In the event that a properly grounded 115 VAC, 60 Hz three (3) prong source is not available, use an ungrounded two (2) wire and a three (3) wire to two (2) wire adapter with built-in grounding pigtail. Ensure that the pigtail is properly connected to a good external ground base or preferably, to an earth ground.

(5) Place power switch to ON; allow the equipment to warm up for 10 minutes, and set MODE SELECTOR switch on the ED-520 to "LO" position.

(6) Select one of the eddy current probes.

(7) Insert the probe into the scanner head as follows: Locate the "T" shaped groove on the connector end of the probe. Line up the "T" on the probe with the index mark on the top surface of the scanner head gear and plug in the probe. Turn the probe clockwise to lock it in position.

(8) Place the SCANNER RPM adjust knob to about 75 RPM.

(9) Place the switch on the scanner head in the EXTEND position and note that the probe will rotate out of the head, extending the probe. The probe will continue to extend until it reaches the limit denoted on the thumbwheel LIMIT SWITCH index mark.

CAUTION

> Do not adjust the thumbwheel limit switch unless the probe is retracted fully in the RETRACT position and has stopped automatically against the bottom stop. Failure to comply could damage the drive mechanism and require disassembly in order to make repairs.

(10) Place the scanner switch in the RETRACT position to rotate the probe into the scanner head. Continue retracting the probe until it has automatically stopped against the bottom stop, i.e., in the fully retracted position.

(11) The difference in probe length between the fully extended and the fully retracted positions is the amount of probe travel as denoted on the LIMIT SWITCH. The LIMIT SWITCH is adjustable from zero (0) to approximately 1-1/2 inches. Determine the total thickness of material (standard or practice sample) which is to be inspected and adjust the LIMIT SWITCH to the appropriate setting while it remains in the fully retracted position.

(12) Place the SCANNER RPM adjust knob in other positions and repeat steps (9) and (10) to note range of scanner speeds available with the system.

Calibration of System/ED-520:

(1) Set the equipment up as directed in previous paragraphs.

(2) Set the MODE SELECTOR switch to "LO" position.

(3) Set the SENSITIVITY control to a mid-range position.

(4) Set the LIFT-OFF/FREQ control 1/2 revolution clockwise from zero at approximately 0050.

(5) Place a 0.007 inch thick piece of masking tape on one of the supplied standards.

NOTE

When calibration is done on the supplied standard, ensure that a location which is free of paint is used.

(6) Place the probe on the standard used for calibration.

(7) Bring the needle on scale with the BALANCE control. If unable to bring the needle back on scale with the BALANCE control, advance the LIFT-OFF/FREQ control clockwise until the needle comes on scale.

(8) Adjust the LIFT-OFF/FREQ control clockwise until the first null point is located, using the BALANCE control to keep the needle on scale. The required null point is recognized when the needle, swinging up scale, stops and reverses direction as the LIFT-OFF/FREQ control is rotated in a constant clockwise direction. If the needle cannot be kept on scale with the BALANCE control continue to rotate the LIFT-OFF/FREQ control until the needle returns to scale.

(9) After the null point is reached, turn the LIFT-OFF/FREQ control counterclockwise a small amount to stay on the front side of the null. Move the probe on to the tape and note direction of the needle deflection. The needle should deflect up scale. If the needle deflects up scale, increase the frequency a small amount by turning the LIFT-OFF/FREQ control counterclockwise. Continue moving the probe from metal to tape and adjusting the two controls until there is a maximum deflection of only one (1) minor division up scale. If the needle deflects down scale when the probe is moved from metal to tape, decrease the frequency by turning the LIFT-OFF/FREQ control a small amount clockwise. Continue to move the probe from metal to tape and adjusting the controls until there is a maximum deflection of only one (1) minor division up scale.

(10) Lock the LIFT-OFF/FREQ control.

NOTE

On most probes, the final calibration frequency will be between 0050 and 0150 on the control dial.

(11) With the probe in the fully retracted position (against the bottom stop) and the LIMIT SWITCH set for an appropriate probe travel, insert the probe into a hole that is to be inspected.

(12) Adjust the BALANCE control for 10 percent of full scale reading.

(13) Index the probe into approximately the middle of the thickest layer of material to be inspected.

(14) Adjust the sensitivity control for 90 percent of full scale reading.

(15) Repeat until 10 percent and 90 percent readings are obtained.

Recorder Set-Up and Familiarity:

(1) Turn the OFF-ON-AUTO switch to the AUTO position so that the recorder and scanner will start or stop at the same time.

(2) Place the recorder SLOW/FAST switch in the SLOW position and the FILTER switch in the 50 RPM position.

(3) Depress the scanner head RETRACT/EXTEND switch to the EXTEND position. Using a Scanner RPM of 75 or less, observe the recording trace on the tape readout as the probe extends. If the trace is too light or too dark, adjust the HEAT control to obtain a desirable trace contrast and width (about mid range of control). Now adjust the ZERO control to bring the trace to the centerline of the tape.

(4) Fully retract the probe using the scanner head switch.

(5) Select one of the standards, either SS-1 or CW-1, and set the scanner head LIMIT SWITCH for full hole-depth probe travel.

(6) Insert the probe into the hole of the standard containing the simulated defect and depress the scanner head RETRACT/EXTEND switch to the EXTEND position. The recorder tape feed and probe rotation will begin simultaneously.

(7) Scan the entire hole surface until the probe reaches its travel limit, at which point the probe and tape motion will cease.

(8) Observe the tape trace of the simulated defect and determine whether the maximum trace excursion is about 80 percent of the distance from the tape centerline to the edge of the grid. If it is not, depress the scanner head RETRACT/EXTEND switch to the RETRACT position until the probe position in the hole coincides with the maximum defect trace excursion. When this point is reached, quickly turn the scanner switch to OFF.

NOTE

The trace pattern will now be reversed relative to the pattern obtained in step 7, since the probe travel direction is now reversed.

(9) Adjust the recorder GAIN to obtain the 80 percent defect trace excursion. Then depress the scanner head switch to the RETRACT position to continue retracting the probe.

(10) Repeat steps (7), (8), and (9) and adjust recorder GAIN, HEAT, or ZERO control as necessary to improve the trace.

(11) Retrace the hole several times and vary, alternately, the recorder FAST/SLOW, SCANNER RPM, and the FILTER controls to study their effects on defect trace resolution and quality and for familiarization.

NOTE

The FD-100 system is now calibrated and set-up for practice inspections. The trainee may repeat any or all portions of these procedures until he is satisfied with his familiarity with the equipment operation.

Practice Inspection:

(1) Set the FD-100 controls as follows:

a.	CHART SPEED FAST/SLOW switch to	SLOW
b.	MODE SELECTOR switch to	LO
c.	Recorder GAIN control to	MAX
d.	SCANNER RPM to	75 RPM
e.	CHART OFF-ON-AUTO switch to	AUTO
f.	FILTER switch to	50 RPM

g. Scanner head switch positions (for reference only)

CENTER POSITION	PROBE OFF
EXTEND POSITION	PROBE INTO HOLE
RETRACT POSITION	PROBE OUT OF HOLE

NOTE

The recorder GAIN can be adjusted as necessary to obtain a satisfactory signal-to-noise relationship at any hole inspected. If a defect trace overruns the tape edge, the GAIN should be reduced.

(2) Fully retract the probe and set the scanner head LIMIT SWITCH for appropriate probe travel for inspecting the open fastener holes in one of the practice specimens as selected.

(3) Insert the probe tip into the first hole to be inspected and inspect the entire surface of each hole. Place the scanner RETRACT/EXTEND switch to the EXTEND position to move the probe into the hole. The recorder and scanner will start at the same time and will stop when the preset probe travel limit is reached.

(4) Observe the tape readouts and meter deflections as the probe moves through the hole. The meter needle should move up scale, down scale, up scale and then down scale as the probe travels from an edge towards the center of one layer on towards the interface and again towards the center of the second layer and then towards the last edge. The slow signal change resulting in a slow needle movement does not cause a change to the recorder because slow changes are filtered. Rapid signal changes may be superimposed on the edge and interface signals; these will show as indications on the recorder and as rapid deflections by the meter needle. Lift-off is usually shown by a recording indication which is 180 degrees out of phase with a crack indication. A crack indication starts in a negative direction, swings positive, and then negative. Lift-off starts in a positive direction, goes negative, and then positive.

(5) There is no need to retract the probe into the scanner to inspect the next hole. Simply remove the probe from the first hole and insert it fully into the second. Depress the scanner RETRACT/EXTEND switch to the RETRACT position and scan the hole surface as the probe is retracted. This recorder trace will be reversed in direction from the trace for the first hole.

(6) Continue inspecting the open fastener holes in the two practice specimens as instructed.

NOTE

If the defect indication on the recorder from a specific hole goes off-scale, or too much noise is observed, decrease the recorder GAIN.

The charts in figure 5 show tape read-out examples taken from the test panels that will be used for training.

NOTE

The shorter readout is produced with the recorder SLOW/FAST switch in the SLOW position; the longer one is produced with the switch in the FAST position.

The diagrams in figures 3 and 4 key the tape examples to specific holes in the test panels.

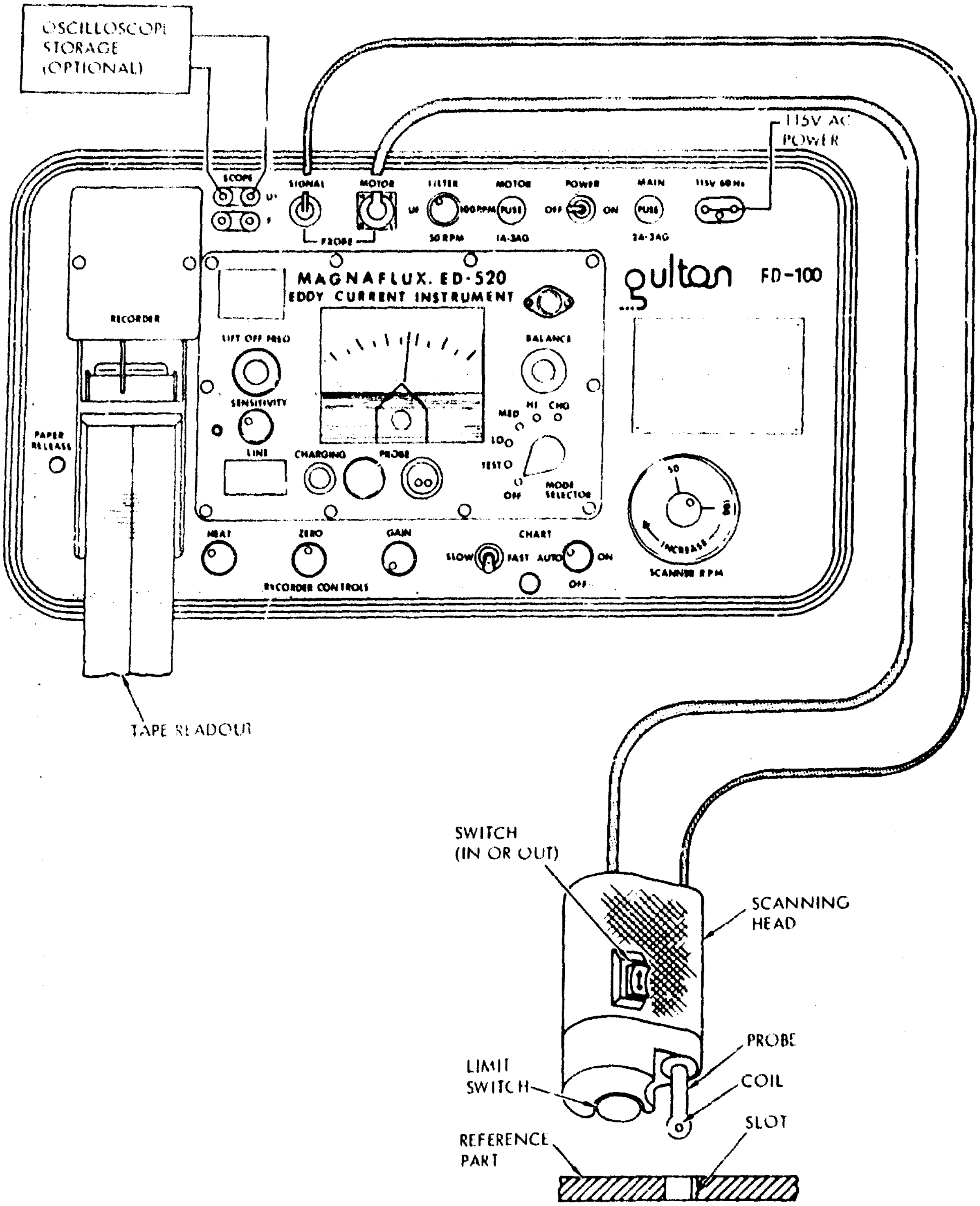
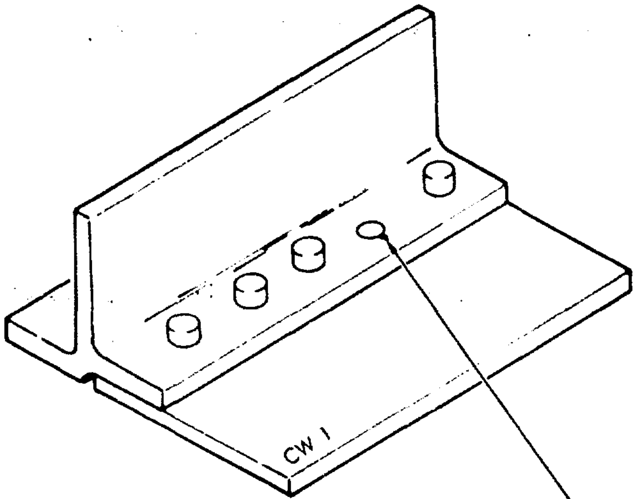
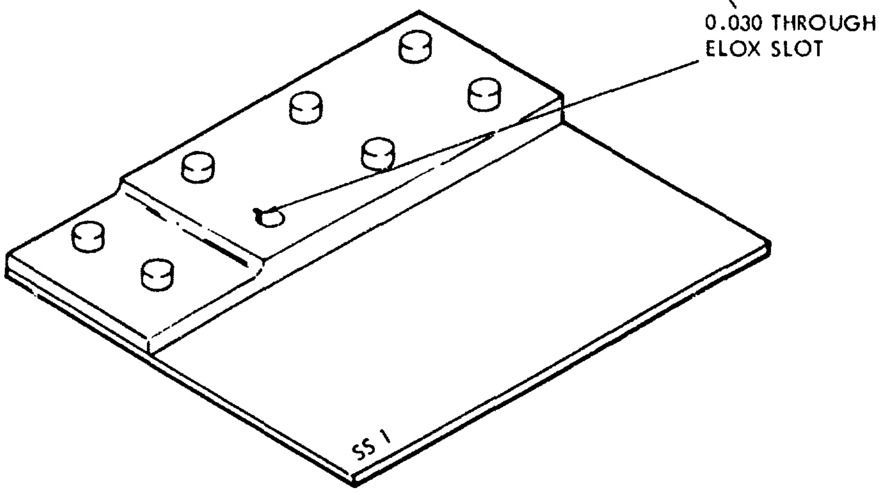


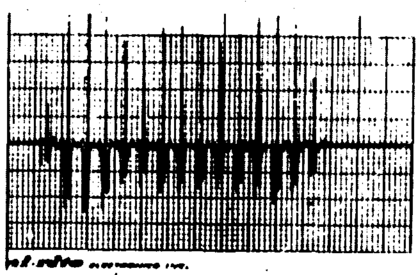
Figure 1. The Gulton Automated Eddy Current Scanning System



CENTER WING STANDARD



SPANWISE SPLICE STANDARD



TYPICAL RECORDING READOUT SHOWING DEFECT

TAPE NO. 1. THIS SHOWS THE ELOX SLOT THROUGH BOTH LAYERS.

Figure 2. Calibration Standards for use with the Automated Eddy Current Scanning System Self Instruction Practice

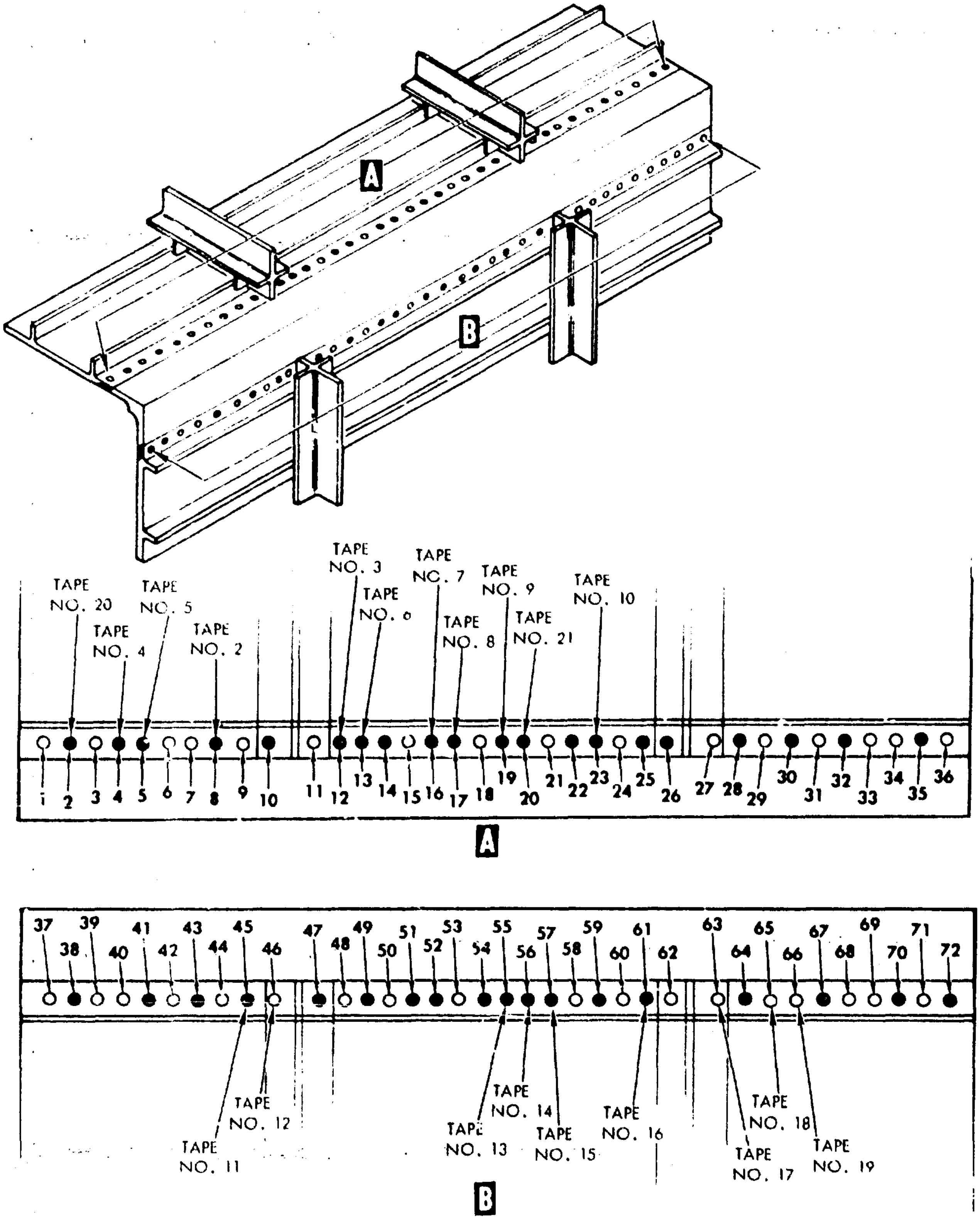


Figure 3. The Spanwise Splice Test Panel

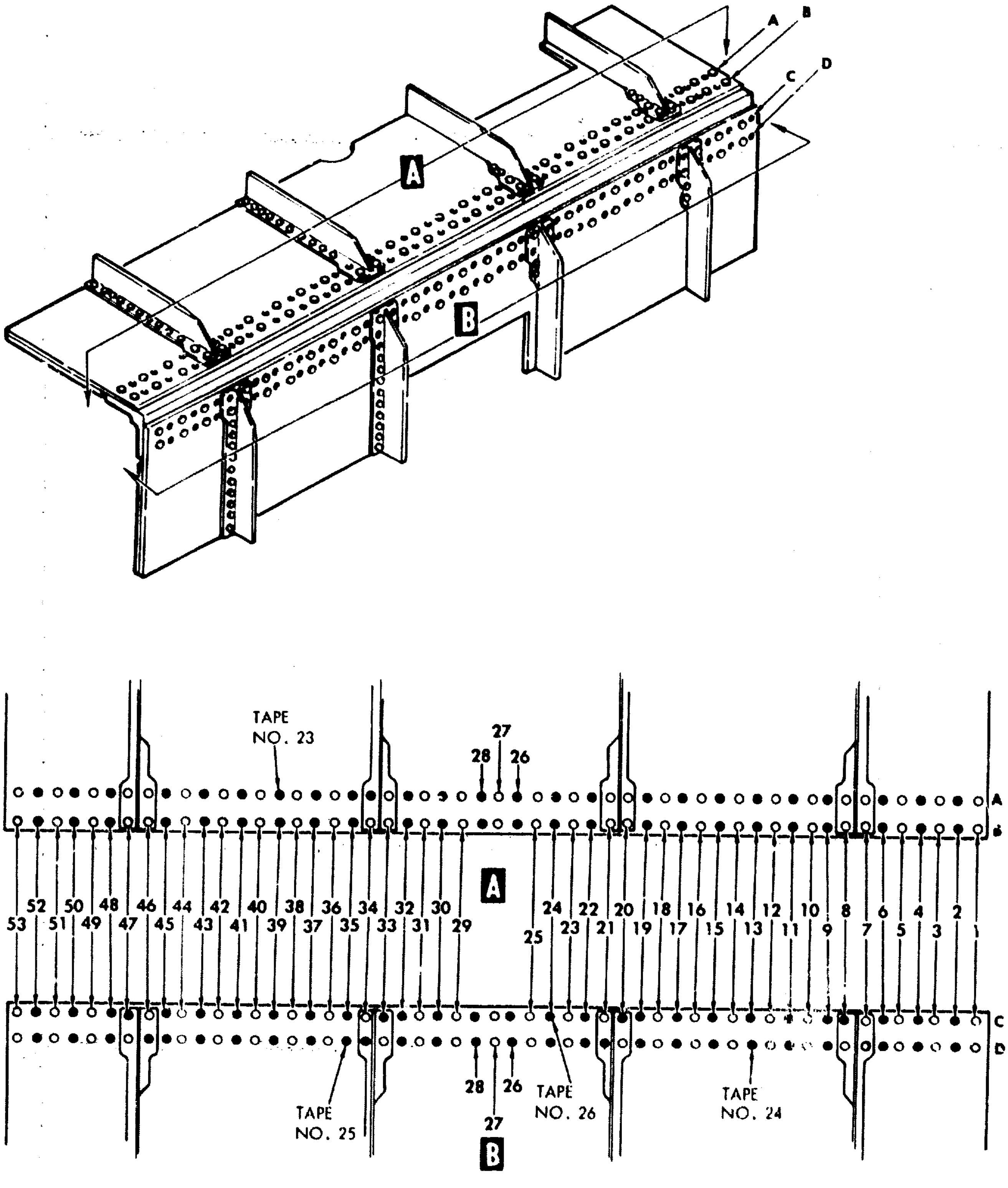
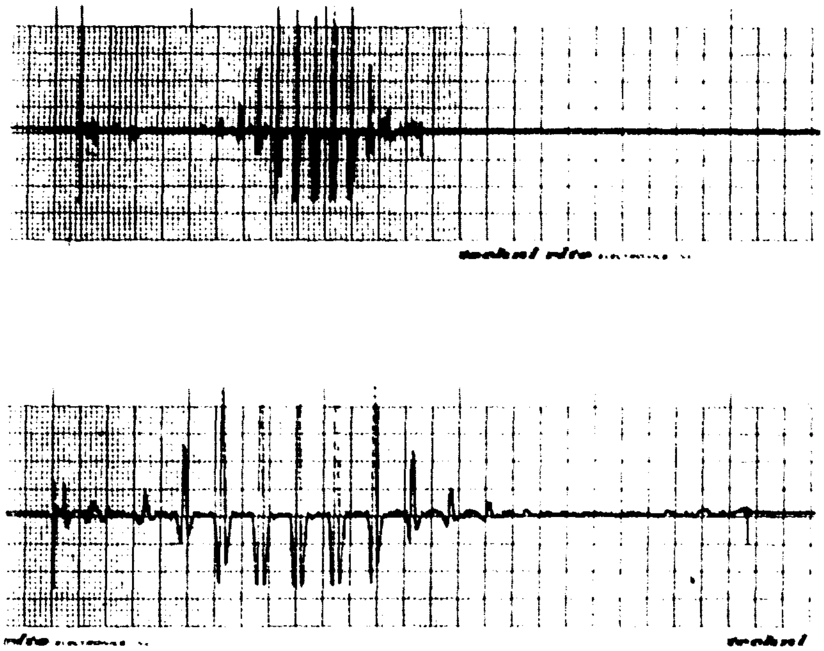
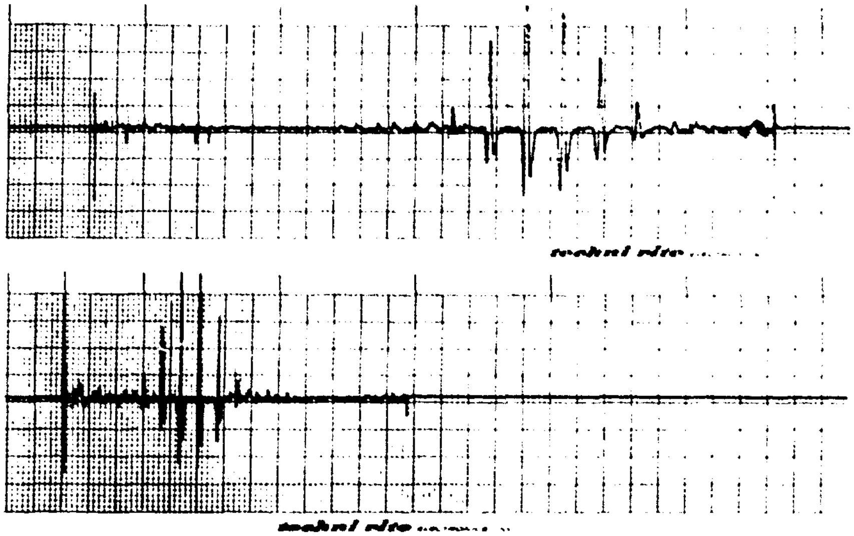


Figure 4. The Center Wing Cap Riser-To-Web Test Panel

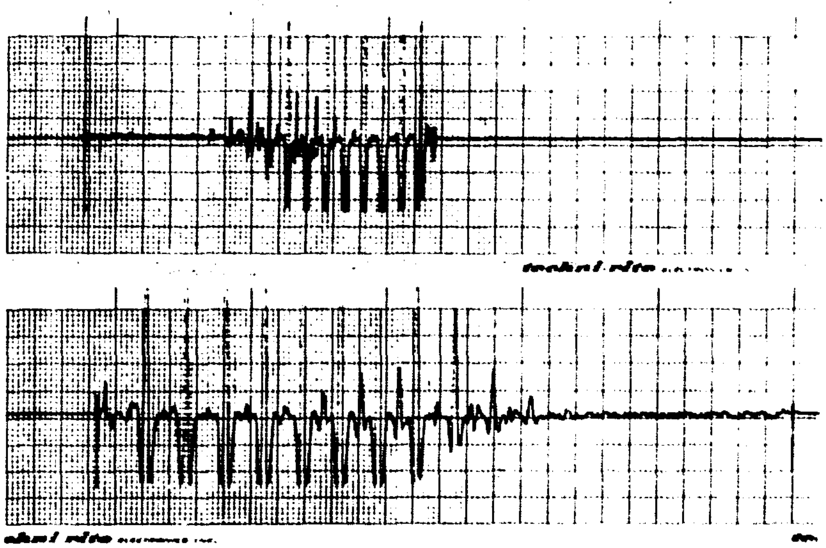


TAPE NO. 2. SCAN OF HOLE NO. 8. THIS SHOWS ONE DEFECT AT THE INTERFACE WITH MINIMUM NOISE.

Figure 5. Gulton System Typical Tape Readouts (Sheet 1 of 11)

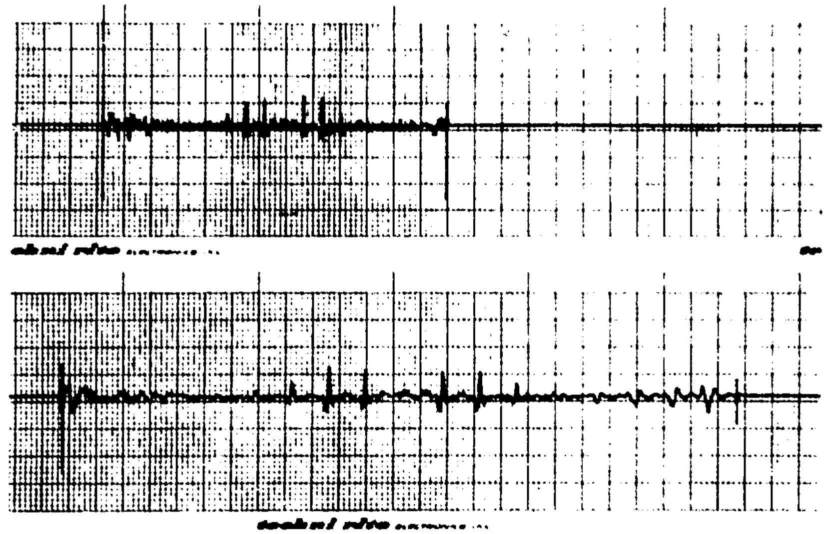


TAPE NO. 3. SCAN OF HOLE NO. 12. THIS SHOWS ONE DEFECT AT THE INTERFACE. NOTE THAT IT IS SMALLER THAN THAT SHOWN IN TAPE 4.

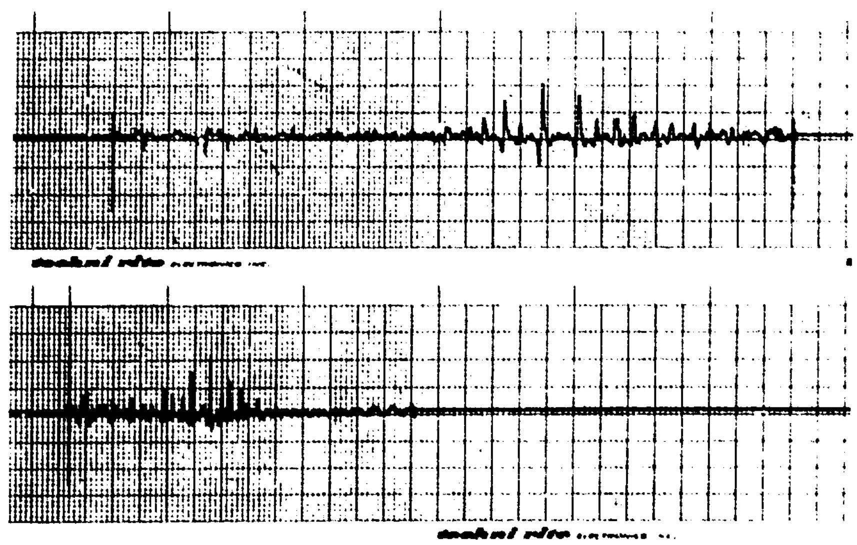


TAPE NO. 4. SCAN OF HOLE NO. 4. THIS SHOWS TWO DEFECTS ON ONE SIDE OF THE INTERFACE. NOTE THAT ONE DEFECT IS SMALLER THAN THE OTHER AND AT AN ANGLE OF APPROXIMATELY 180 DEGREES FROM IT.

Figure 5. Gulton System Typical Tape Readouts (Sheet 2 of 11)

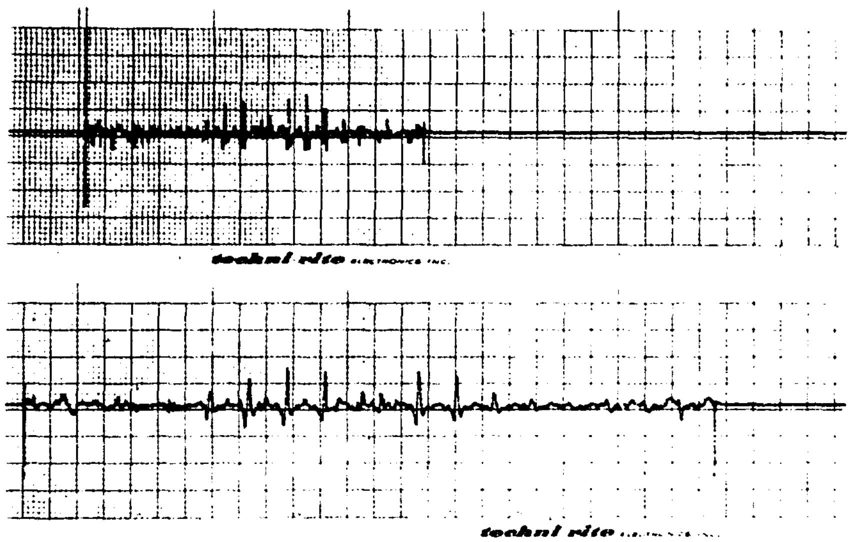


TAPE NO. 5. SCAN OF HOLE NO. 5. THIS SHOWS TWO SMALL DEFECTS, ONE ON EACH SIDE OF THE INTERFACE AND IN APPROXIMATELY THE SAME LOCATION.

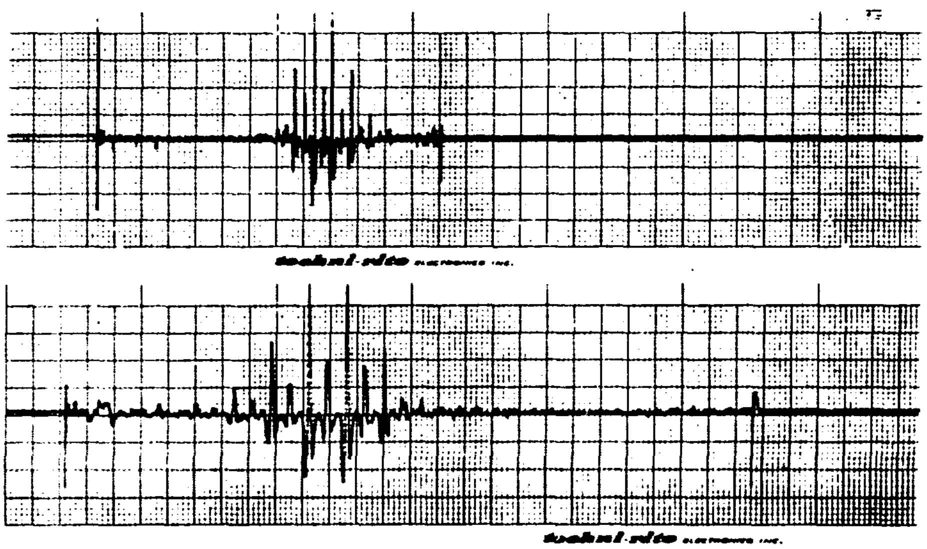


TAPE NO. 6. SCAN OF HOLE NO. 13. THIS SHOWS NOISE THROUGHOUT THE HOLE AND A DEFECT ON ONE SIDE OF THE INTERFACE. NOISE MAY BE CAUSED BY A ROUGH SURFACE, CONTAMINATION IN THE HOLE, OR IMPROPER SET UP, ETC.

Figure 5. Gulton System Typical Tape Readouts (Sheet 3 of 11)

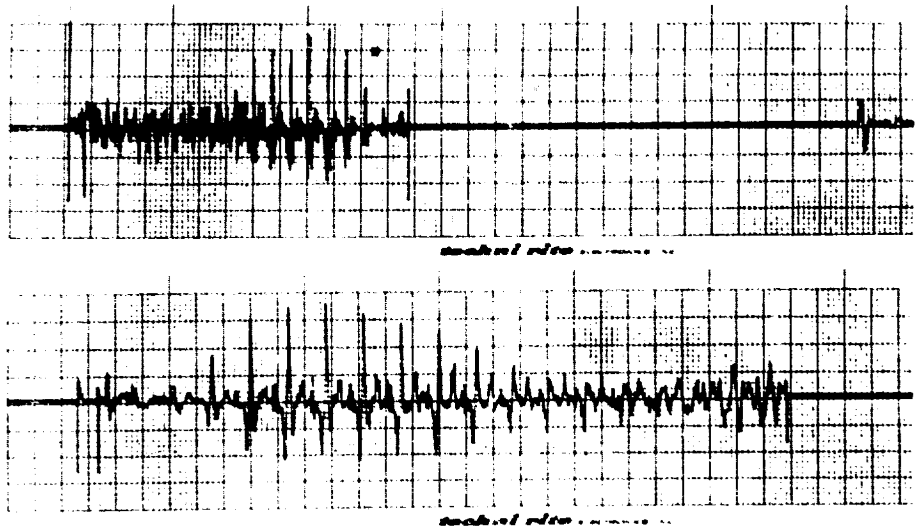


TAPE NO. 7. SCAN OF HOLE NO. 16. THIS SHOWS TWO CRACKS, ONE ON EACH SIDE OF THE INTERFACE AT AN ANGLE OF APPROXIMATELY 180 DEGREES FROM EACH OTHER.

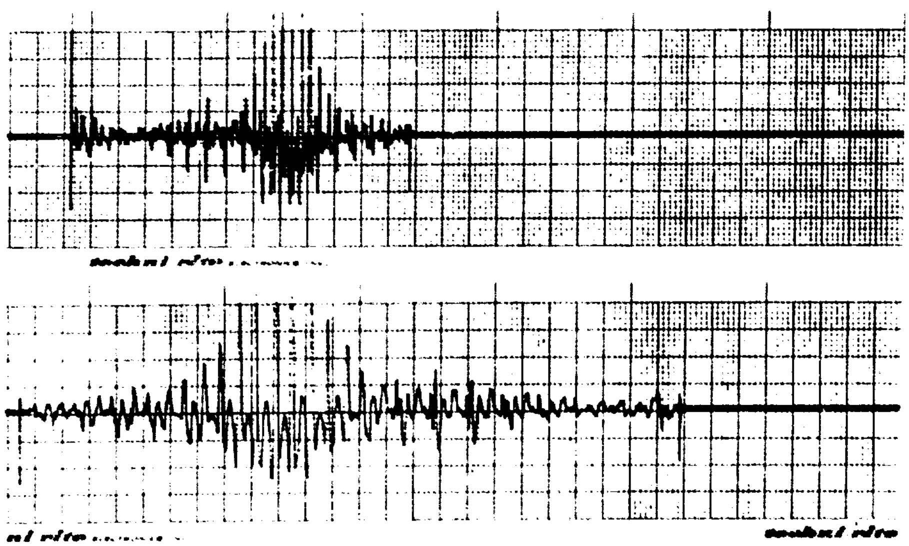


TAPE NO. 8. SCAN OF HOLE NO. 17. THIS SHOWS TWO CRACKS ON THE SAME SIDE OF THE INTERFACE AT AN ANGLE OF APPROXIMATELY 180 DEGREES FROM EACH OTHER.

Figure 5. Gulton System Typical Tape Readouts (Sheet 4 of 11)

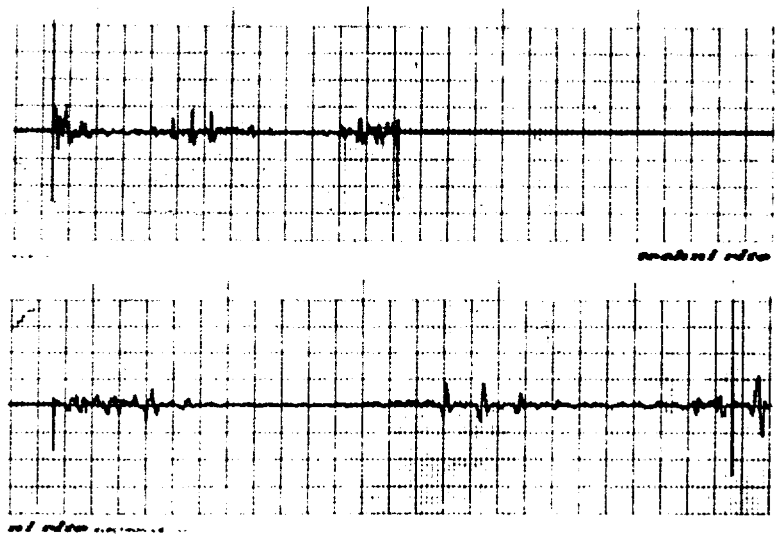


TAPE NO. 9. SCAN OF HOLE NO. 19. ALTHOUGH THIS HOLE PRODUCED A LOT OF NOISE, A CRACK CAN BE DETECTED IN ONE SIDE OF THE INTERFACE.

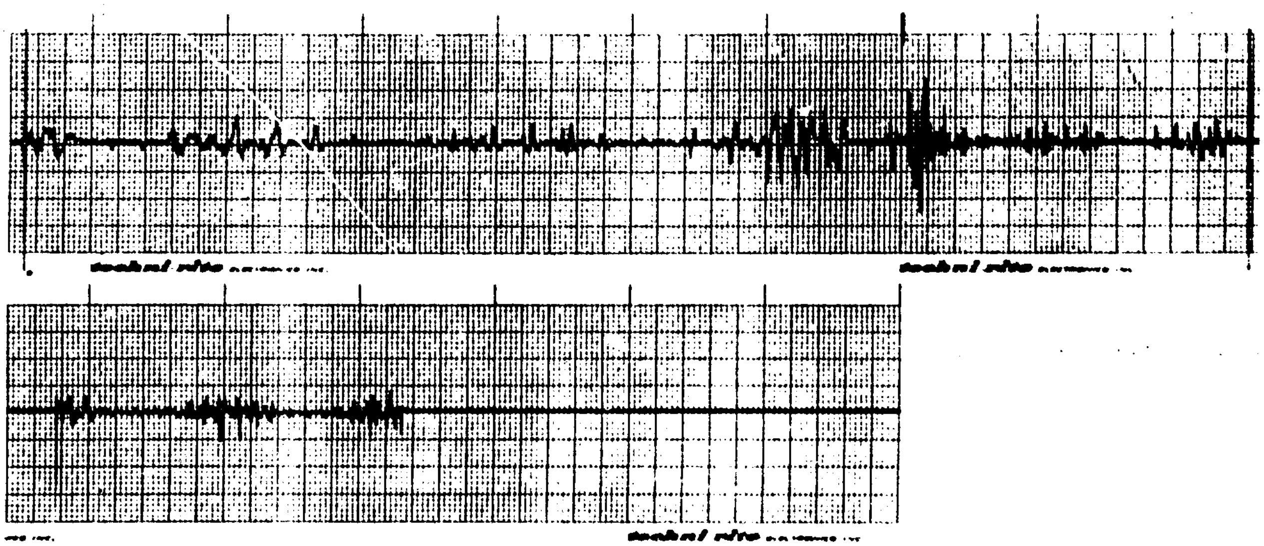


TAPE NO. 10. SCAN OF HOLE NO. 23. THIS SHOWS THREE DEFECTS. TWO DEFECTS ARE ON ONE SIDE OF THE INTERFACE AT AN ANGLE OF 180 DEGREES FROM EACH OTHER, THE THIRD IS A CRACK ON THE OTHER SIDE OF THE INTERFACE. NOISE SHOWS THROUGHOUT THE HOLE.

Figure 5. Gulton System Typical Tape Readouts (Sheet 5 of 11)

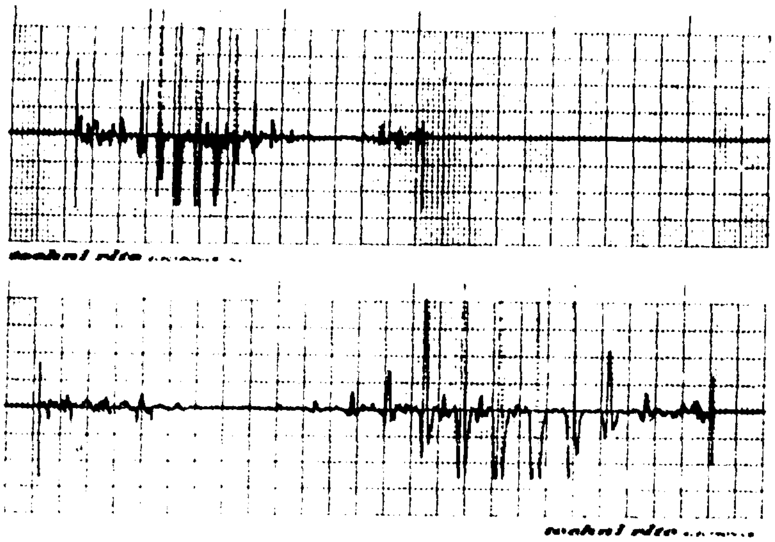


TAPE NO. 11. SCAN OF HOLE NO. 45. THIS SHOWS A SMALL CRACK ON ONE SIDE OF THE INTERFACE.

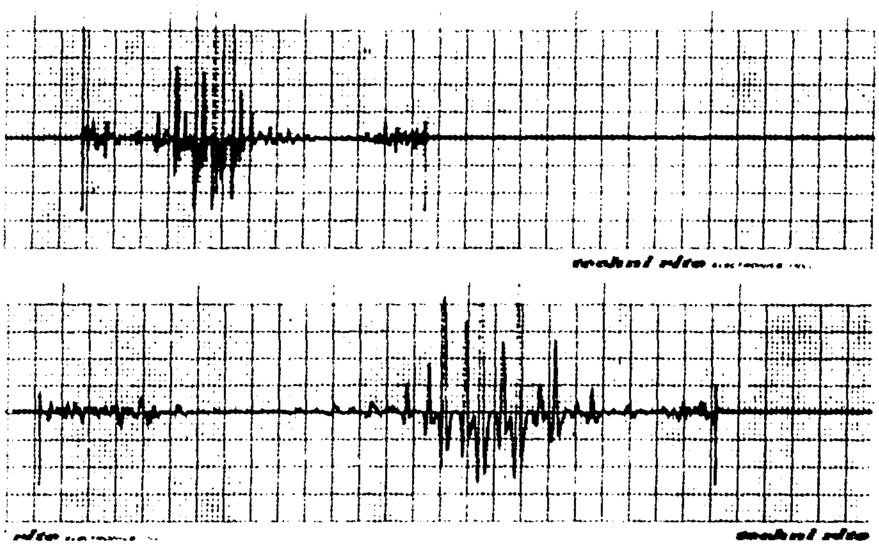


TAPE NO. 12. SCAN OF HOLE NO. 46. THIS SHOWS A SMALL CRACK ON ONE SIDE OF THE INTERFACE.

Figure 5. Gulton System Typical Tape Readouts (Sheet 6 of 11)

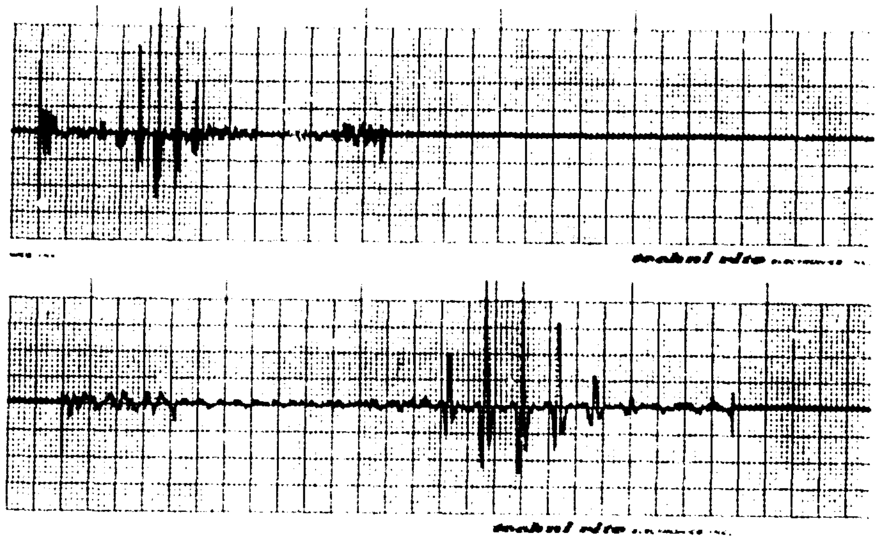


TAPE NO. 13. SCAN OF HOLE NO. 55. THIS SHOWS A LARGE CRACK ON ONE SIDE OF THE INTERFACE.

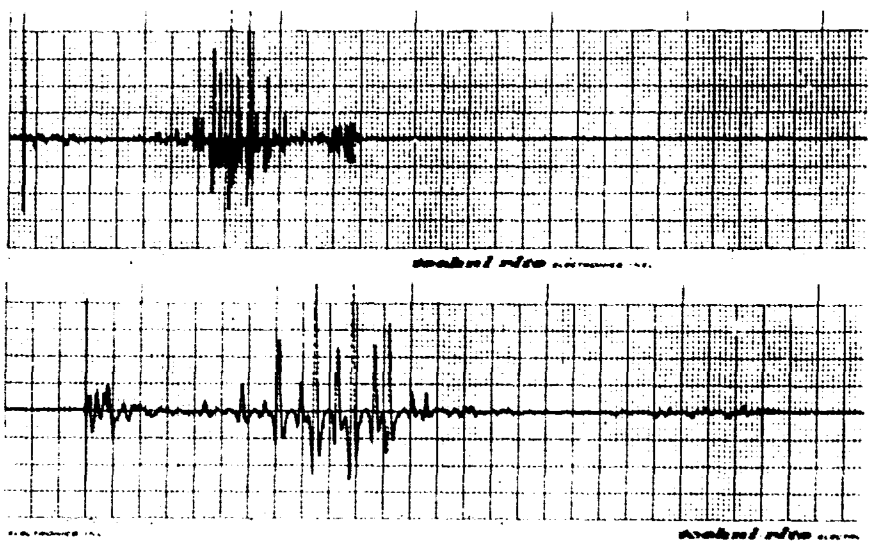


TAPE NO. 14. SCAN OF HOLE NO. 56. THIS SHOWS TWO CRACKS ON THE SAME SIDE OF THE INTERFACE AT AN ANGLE OF APPROXIMATELY 180 DEGREES FROM EACH OTHER.

Figure 5. Gulton System Typical Tape Readouts (Sheet 7 of 11)

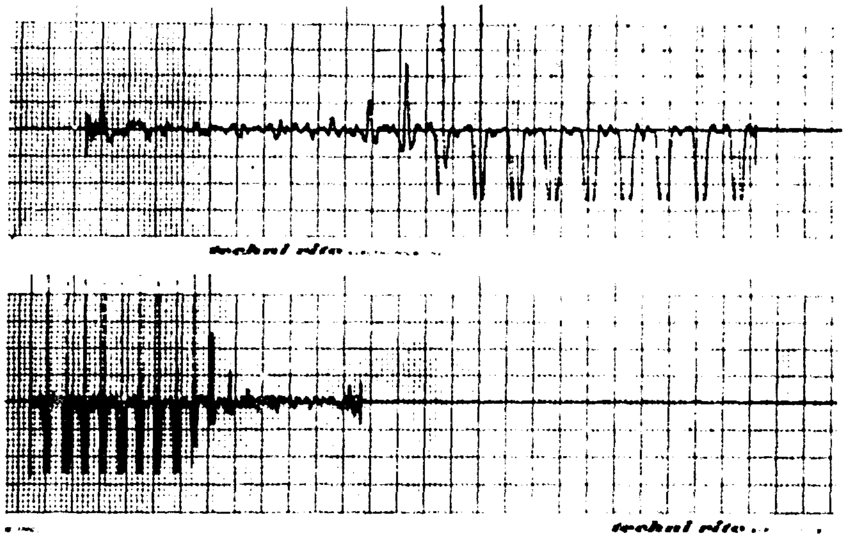


TAPE NO. 15. SCAN OF HOLE NO. 57. THIS SHOWS A LARGE CRACK ON ONE SIDE OF THE INTERFACE.

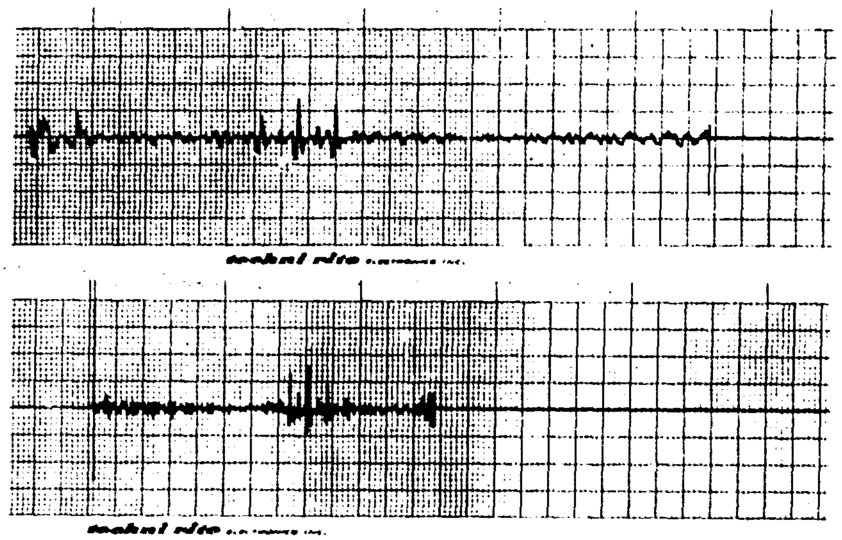


TAPE NO. 16. SCAN OF HOLE NO. 61. THIS SHOWS TWO DEFECTS ON THE SAME SIDE OF THE INTERFACE AT AN ANGLE OF APPROXIMATELY 120 DEGREES FROM EACH OTHER.

Figure 5. Gulton System Typical Tape Readouts (Sheet 8 of 11)

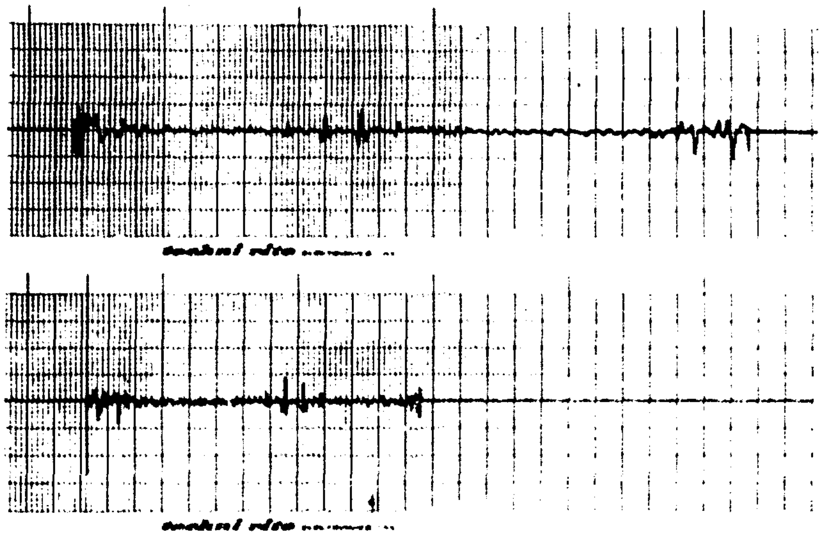


TAPE NO. 17. SCAN OF HOLE NO. 63. THIS SHOWS A LARGE CRACK EXTENDING THROUGH ONE LAYER OF MATERIAL.

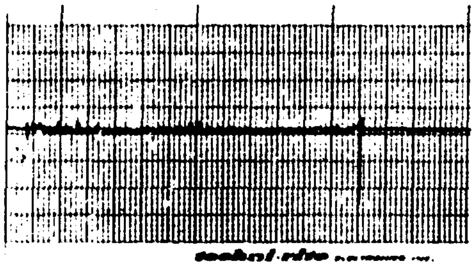


TAPE NO. 18. SCAN OF HOLE NO. 65. THIS SHOWS A SMALL CRACK ON ONE SIDE OF THE INTERFACE.

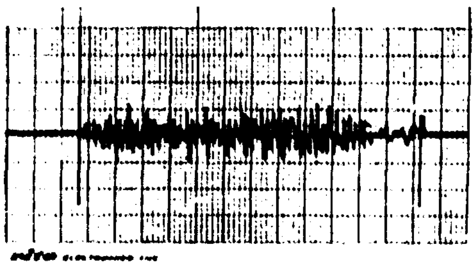
Figure 5. Gulton System Typical Tape Readouts (Sheet 9 of 11)



TAPE NO. 19. SCAN OF HOLE NO. 66. THIS SHOWS A SMALL CRACK ON ONE SIDE OF THE INTERFACE.

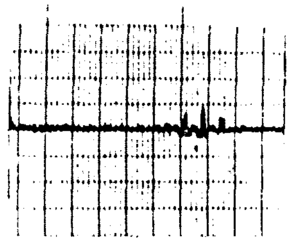


TAPE NO. 20. SCAN OF HOLE NO. 2. THIS SHOWS TYPICAL NOISE FROM A HOLE. NO DEFECTS WERE DETECTED.

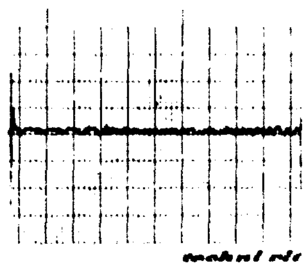


TAPE NO. 21. SCAN OF HOLE NO. 20. THIS SHOWS EXCESSIVE NOISE FROM A HOLE. NO DEFECTS WERE DETECTED.

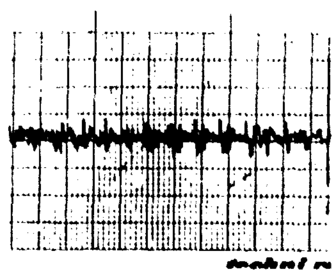
Figure 5. Gulton System Typical Tape Readouts (Sheet 10 of 11)



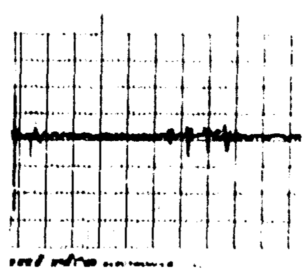
TAPE NO. 22. SCAN OF HOLE NO. A39. THIS SHOWS A TYPICAL SMALL DEFECT ON ONE SIDE OF THE INTERFACE. THE BACKGROUND NOISE IS TYPICAL FOR A SMOOTH HOLE.



TAPE NO. 23. SCAN OF HOLE NO. D13. THIS SHOWS TYPICAL NOISE FROM HOLES IN THIS SECTION OF THE STRUCTURE.



TAPE NO. 24. SCAN OF HOLE NO. D35. THIS SHOWS EXCESSIVE NOISE WHICH INDICATES A ROUGH HOLE, A HOLE CONTAMINATED WITH SEALANT OR IMPROPER SET UP.



TAPE NO. 25. SCAN OF HOLE NO. C24. THIS SHOWS LIFT-OFF WHICH CAN BE CAUSED BY A DEPRESSION OR AN ISOLATED PIECE OF SEALANT. NOTE THAT THE INDICATION STARTS IN THE POSITIVE DIRECTION AND THE MAXIMUM AMPLITUDE IS IN THE NEGATIVE DIRECTION.

Figure 5. Gulton System Typical Tape Readouts (Sheet 11 of 11)

OPERATIONAL SUPPLEMENT NO. 1

TECHNICAL MANUAL

NONDESTRUCTIVE INSPECTION

RELIABILITY PROGRAM

THIS PUBLICATION SUPPLEMENTS TECHNICAL MANUAL NONDESTRUCTIVE INSPECTION, RELIABILITY PROGRAM. Reference to this supplement will be made on the title page of the basic publication by personnel responsible for maintaining the publication in current status.

19 NOVEMBER 1976

1. PURPOSE.

The purpose of this supplement is to add procedures for operation of new NDI equipment, the Gulton Automatic Eddy Current System.

2. INSTRUCTIONS.

A. On page 1-1, add the following entries to the table of contents immediately following the BOLT HOLE INSPECTION TECHNIQUE listing.

B. On page 1-9, add the following paragraphs immediately following paragraph 1-13.e.

1-13A. EDDY CURRENT METHOD USING THE GULTON AUTOMATIC EDDY CURRENT SCANNING SYSTEM.

1-13B. AUTOMATED EDDY CURRENT INSTRUMENT SET UP AND CALIBRATION. (See Figure 1-6A.) The following instrument set up and calibration instructions are to be used when required for automated procedures in lieu of the manual eddy current bolt hole procedures for structure samples D, E, and F. The Gulton FD-100 Automatic Eddy Current Scanning System was used in formulating the Automated Eddy Current Inspection Procedures in Section II, Structure Samples D, E, and F.

a. Equipment Set Up:

(1) Open the FD-100 instrument case and remove all cables and the scanner head from the storage compartment.

(2) Connect the scanner head cable to the MOTOR connector on the FD-100 instrument.

(3) Connect the RF signal cable to the SIGNAL connector on the FD-100 instrument.

(4) Connect the three-wire power cable to the FD-100 and plug into a 60 H_Z 115 VAC grounded outlet.

WARNING

The FD-100 system uses a safety grounded, three-wire AC power input. DO NOT ATTEMPT TO CHEAT OR DEFEAT THE BUILT-IN SAFETY GROUND. In the event that a properly grounded 115 VAC, 60 H_Z three-prong source is not available and it is desired to use an ungrounded two-wire source, use a three-wire to two-wire adapter with built-in grounding pigtail. Ensure that the pigtail is properly connected to a good external ground base or, preferably, to an earth ground.

(5) Place power switch to ON, allow the equipment to warm up for ten (10) minutes, and set MODE SELECTOR switch on the ED-520 to "LO" position.

(6) Select the eddy current probe which is to be used.

(7) Insert the probe into the scanner head as follows: Locate the "T" shaped groove on the connector end of the probe. Line up the "T" on the probe with the index mark on the top surface of the scanner head gear and plug in the probe. Turn the probe clockwise to lock in position. When withdrawing the probe following an inspection, locate the center of the "T" by feel and pull straight out. It may be necessary to rotate the probe out about one (1) inch in order to get a hold on the probe. The probe plugs into one end of a rotating double ended mercury wetted connector; the other end of the connector is attached to the coaxial signal cable on the FD-100 control panel.

(8) Rotate the probe into the scanning head until the scanner automatically stops against the bottom stop.

CAUTION

Do not adjust the thumbwheel limit switch adjustment until the scanner has stopped automatically against the bottom stop. Failure to comply could damage the drive mechanism and require disassembly in order to make repairs.

(9) Rotate the scanner thumbwheel for desired probe travel. (Adjustable from zero to approximately 1-1/2-inches.)

b. Calibration:

(1) Set the equipment up as directed in paragraph a.

(2) Set the MODE SELECTOR switch to "LO" position.

(3) Set the SENSITIVITY control to a mid range position.

(4) Set the LIFT-OFF/FREQ control 1/2 revolution clockwise from zero at approximately 0050.

(5) Place a 0.007 inch thick piece of masking tape on either supplied standard.

NOTE

When calibration is done on the supplied standard, ensure that a location which is free of paint is used.

(6) Place the probe on the material used for calibration.

(7) Bring the needle on scale with the BALANCE control. If unable to bring the needle back on scale with the BALANCE control, advance the LIFT-OFF/FREQ control clockwise until the needle comes on scale.

(8) Adjust the LIFT-OFF/FREQ control clockwise until the first null point is located; using the BALANCE control to keep the needle on scale. The required null point is recognized when the needle, swinging up scale, stops and reverses direction as the LIFT-OFF/FREQ control is rotated in a constant clockisc direction. If the needle cannot be kept on scale with the BALANCE control, continue to rotate the LIFT-OFF/FREQ control until the needle returns to scale.

(9) After the null point is reached, turn the LIFT-OFF/FREQ control counterclockwise a small amount to stay on the front side of the null. Move the probe on to the tape and note direction of needle deflection. The needle should deflect up scale. If the needle deflects up scale, increase the frequency by turning the LIFT-OFF/FREQ control a small amount counterclockwise. Continue moving the probe from metal to tape and adjusting the two controls until there is a maximum deflection of only one (1) minor division up scale. If the needle deflects down scale when the probe is moved from metal to tape, decrease the frequency by turning the LIFT-OFF/FREQ control a small amount clockwise. Continue to move the probe from metal to tape and adjusting the controls until there is a maximum deflection of only one (1) minor division up scale.

(10) Lock the LIFT-OFF/FREQ control.

NOTE

On most probes the final calibration frequency will be between 0050 and 0150 on the control dial.

C. After page 1-11, add figures No. 1-6A and 1-6B.

D. On page 2-21, add the following procedure after NDI Procedure No. 2.

2-21A. NDI PROCEDURE NO. 3 - AUTOMATED EDDY CURRENT BOLT HOLE INSPECTION.

a. NDI equipment:

(1) Crack Detector, Gulton FD-100 Automatic Eddy Current Bolt Hole Scanning System.

(2) Probes, Bolt Hole, 3/16-inch diameter, 1/4-inch diameter, and 5/16-inch diameter; P/N 402748-1, -3, -5 or equivalent.

(3) Calibration Standard, Aluminum. (See Figure 1-6B.)

b. Access: The fastener holes are readily accessible.

c. Preparation of part: Remove all sealant and coatings from the hole.

d. Instrument settings/calibration: Refer to paragraph titled Automated Eddy Current Instrument Set Up and Calibration, in Section 1 of this manual.

e. ED 250 equipment set up prior to inspection:

(1) Set the equipment up and calibrate in accordance with paragraph 1-13B.

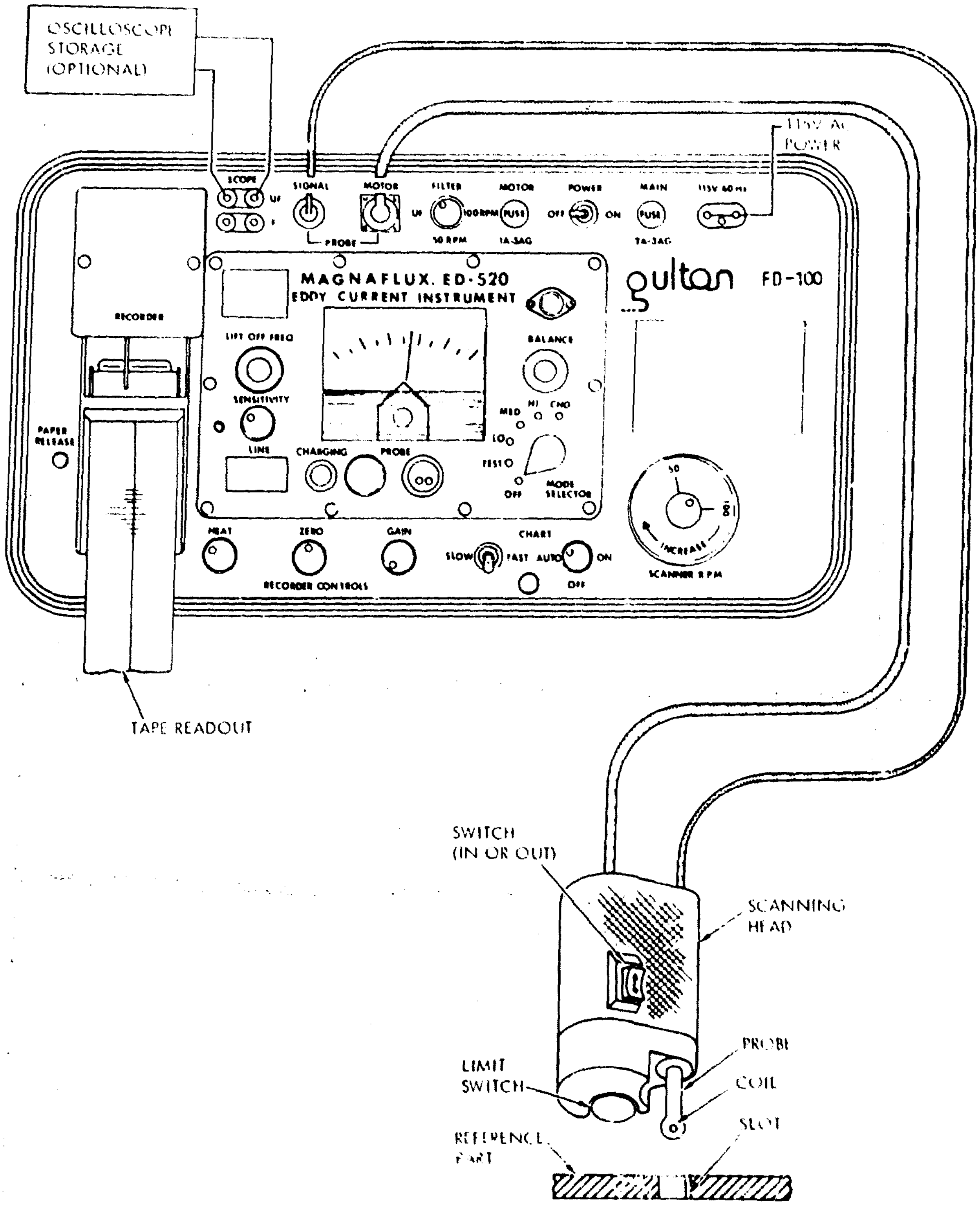


Figure 1-6A. The Gulton Automated Eddy Current Scanning System.

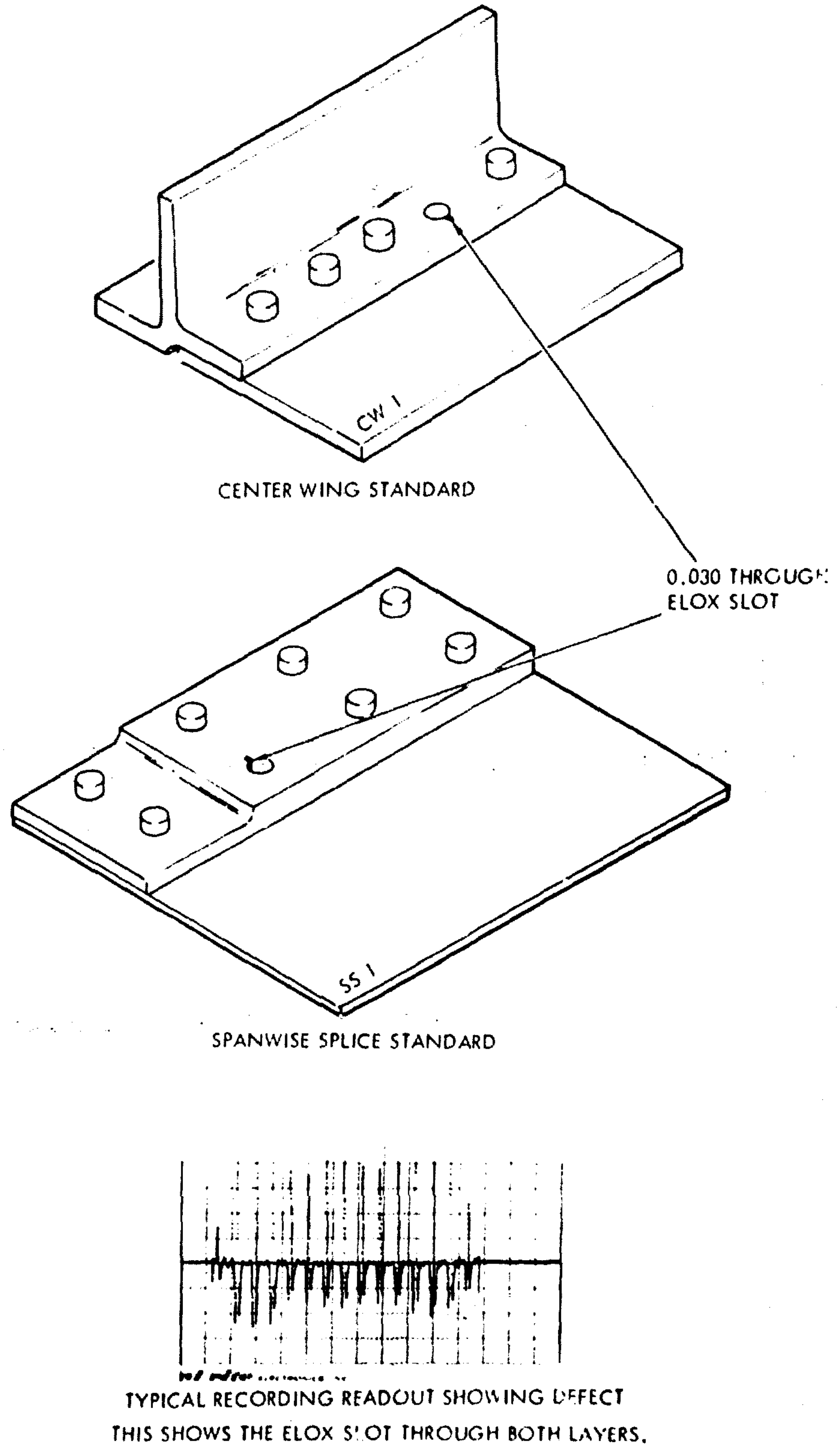


Figure 1-6B. Calibration Standards for the Automated Eddy Current Inspections.

CAUTION

Do not adjust the thumbwheel limit switch adjustment until the scanner has stopped automatically against the bottom stop. Failure to comply could damage the drive mechanism and require disassembly in order to make repairs.

(2) Set the maximum probe travel limit to the depth of the hole that is to be inspected by referring to the dimensioned drawings for structure sample D.

(3) Move the probe to the bottom stop (full retracted position) and insert the probe into the hole that is to be inspected.

(4) Adjust the BALANCE control for 10 percent of full scale reading.

(5) Index the probe into approximately the middle of the thickest layer of material to be inspected.

(6) Adjust the sensitivity control for 90 percent of full scale reading.

(7) Repeat until 10 percent and 90 percent readings are obtained.

f. Set the FD-100 controls as follows:

(1)	Chart Speed	SLOW
(2)	Mode Selector Switch (Function)	LO
(3)	Recorder Gain	MAX
(4)	Scan	75 RPM
(5)	Auto-Off-On	AUTO
(6)	Filter	50 RPM
(7)	Scanner Head Switch Positions	
	Center	OFF
	Extend	INTO HOLE
	Retract	OUT OF HOLE

NOTE

Recorder gain may need to be changed in order to obtain the best signal to noise ratio.

g. Inspection: Scan the entire inner surfaces of the indicated holes of each diameter in the sample as illustrated in figure 1-6B.

NOTE

Ensure that the probe is set at the bottom stop (full retracted position) before adjusting the limit switch.

(1) Place the probe in the hole that is to be inspected and depress the switch on the scanner in the direction in which the probe is to travel.

NOTE

The recorder and scan will start and stop simultaneously.

(2) Observe the meter and chart deflections. A defect indication will be noted by a sharp meter deflection down scale and a chart deflection down scale, then up scale, and then down scale again.

(3) If a defect is indicated, clean the hole and repeat the inspection. If the defect indication persists, report the hole as having a defect.

NOTE

If the defect indication on the recorder from a specific hole goes off scale, or too much noise is observed, decrease the gain.

(4) Record the results of the inspection on applicable drawings or forms as instructed during the technician briefing.

(5) Identify all recording charts by marking the ends with the following information:

(a) Structure sample designation.

(b) Hole number.

(c) Date.

(d) Technician's program identification number.

(6) Mark individual recordings as follows:

(a) Hole number.

(b) Defect indication if any.

E. On page 2-26, revise paragraph 2-25 title to read as follows:

2-25. NDI PROCEDURE NO. 1 - EDDY CURRENT BOLT HOLE.

F. On page 2-26, add the following procedure.

2-25A. NDI PROCEDURE NO. 2 - AUTOMATED EDDY CURRENT BOLT HOLE INSPECTION.

a. NDI equipment

(1) Crack Detector, Gulton FD-100 Automatic Eddy Current Bolt Hole Scanning System.

(2) Probes, Bolt Hole, 5/16-inch diameter, P/N 402748-5.

(3) Calibration Standard, Aluminum. (See Figure 1-6B.)

b. Access: The fasteners are readily accessible.

c. Preparation of part: Remove all sealant and coatings from the hole.

d. Instrument settings/calibration: Refer to paragraph titled Automated Eddy Current Instrument Set Up and Calibration, in Section 1 of this manual.

e. ED 250 Equipment set up prior to inspection:

(1) Set the equipment up and calibrate in accordance with paragraph 1-13B.

CAUTION

Do not adjust the thumbwheel limit switch adjustment until the scanner has stopped automatically against the bottom stop. Failure to comply could damage the drive mechanism and require disassembly in order to make repairs.

(2) Set the maximum probe travel limit to the depth of the hole that is to be inspected by referring to the dimensioned drawings for structure sample E.

(3) Move the probe to the bottom stop (full retracted position) and insert the probe into the hole that is to be inspected.

(4) Adjust the BALANCE control for 10 percent of full scale reading.

(5) Index the probe into approximately the middle of the thickest layer of material to be inspected.

(6) Adjust the sensitivity control for 90 percent of full scale reading.

(7) Repeat until 10 percent and 90 percent readings are obtained.

f. Set the FD-100 controls as follows:

(1) Chart Speed	SLOW
(2) Mode Selector Switch (Function)	LO
(3) Recorder Gain	MAX
(4) Scan	75 RPM
(5) Auto-Off-On	AUTO
(6) Filter	50 RPM
(7) Scanner Head Switch Positions	
Center	OFF
Extend	INTO HOLE
Retract	OUT OF HOLE

NOTE

Recorder gain may need to be changed in order to obtain the best signal to noise ratio.

g. Inspection: Scan the entire inner surfaces of the indicated holes of each diameter in the sample as illustrated in figure 1-6B.

NOTE

Ensure that the probe is set at the bottom stop (full retracted position) before adjusting the limit switch.

(1) Place the probe in the hole that is to be inspected and depress the switch on the scanner in the direction in which the probe is to travel.

NOTE

The recorder and scan will start and stop simultaneously.

(2) Observe the meter and chart deflections. A defect indication will be noted by a sharp meter deflection down scale and a chart deflection down scale, then up scale, and then down scale again.

(3) If a defect is indicated, clean the hole and repeat the inspection. If the defect indication persists, report the hole as having a defect.

NOTE

If the defect indication on the recorder from a specific hole is too large, or too much noise is observed, decrease the gain.

(4) Record the results of the inspection on applicable drawings or forms as instructed during the technician briefing.

(5) Identify all recording charts by marking the ends with the following information:

(a) Structure sample designation.

(b) Hole number.

(c) Date.

(d) Technician's program identification number.

(6) Mark individual recordings as follows:

(a) Hole number.

(b) Defect indication if any.

G. On page 2-29, add the following procedure after NDI Procedure No. 2.

2-30A. NDI PROCEDURE NO. 3 - AUTOMATED EDDY CURRENT BOLT HOLE INSPECTION.

a. NDI equipment:

(1) Crack Detector, Gulton FD-100 Automatic Eddy Current Bolt Hole Scanning System.

(2) Probes, Bolt Hole, 1/4-inch diameter, and 5/16-inch diameter; P/N 402748 -3, -5 or equivalent.

(3) Calibration Standard, Aluminum. (See Figure 1-6B.)

b. Access: The fasteners are readily accessible.

c. Preparation of part: Remove all sealant and coatings from the hole.

d. Instrument settings/calibration: Refer to paragraph titled Automated Eddy Current Instrument Set Up and Calibration, in Section 1 of this manual.

e. ED 250 Equipment set up prior to inspection:

(1) Set the equipment up and calibrate in accordance with paragraph 1-13B.

CAUTION

Do not adjust the thumbwheel limit switch adjustment until the scanner has stopped automatically against the bottom stop. Failure to comply could damage the drive mechanism and require disassembly in order to make repairs.

(2) Set the maximum probe travel limit to the depth of the hole that is to be inspected by referring to the dimensioned drawings for structure sample F.

(3) Move the probe to the bottom stop (full retracted position) and insert the probe into the hole that is to be inspected.

(4) Adjust the BALANCE control for 10 percent of full scale reading.

(5) Index the probe into approximately the middle of the thickest layer of material to be inspected.

(6) Adjust the sensitivity control for 90 percent of full scale reading.

(7) Repeat until 10 percent and 90 percent readings are obtained.

f. Set the FD-100 controls as follows:

(1)	Chart Speed	SLOW
(2)	Mode Selector Switch (Function)	LO
(3)	Recorder Gain	MAX
(4)	Scan	75 RPM
(5)	Auto-Off-On	AUTO
(6)	Filter	50 RPM
(7)	Scanner Head Switch Positions	
	Center	OFF
	Extend	INTO HOLE
	Retract	OUT OF HOLE

NOTE

Recorder gain may need to be changed in order to obtain the best signal to noise ratio.

g. Inspection: Scan the entire inner surfaces of the indicated holes of each diameter in the sample as illustrated in figure 1-6B.

NOTE

Ensure that the probe is set at the bottom stop (full retracted position) before adjusting the limit switch.

(1) Place the probe in the hole that is to be inspected and depress the switch on the scanner in the direction in which the probe is to travel.

NOTE

The recorder and scan will start and stop simultaneously.

(2) Observe the meter and chart deflections. A deflect indication will be noted by a sharp meter deflection down scale and a chart deflection down scale, then up scale, and then downscale again.

(3) If a defect is indicated, clean the hole and repeat the inspection. If the defect indication persists, report the hole as having a defect.

NOTE

If the defect indication on the recorder from a specific hole is too large, or too much noise is observed, decrease the gain.

(4) Record the results of the inspection on applicable drawings or forms as instructed during the techniques briefing.

(5) Identify all recording charts by marking the ends with the following information:

(a) Structure sample designation.

(b) Hole number.

(c) Date.

(d) Technician's program identification number.

(6) Mark individual recordings as follows:

(a) Hole number.

(b) Defect indication if any.

THE END

APPENDIX B

SELF INTRODUCTION FOR THE ULTRASONIC SA-ALC 360 DEGREE ROTATIONAL SCANNER SYSTEM

and

OPERATIONAL SUPPLEMENT NO. 2 - TECHNICAL MANUAL NONDESTRUCTIVE INSPECTION RELIABILITY PROGRAM

SELF INTRODUCTION FOR THE ULTRASONIC SA-ALC 360 DEGREE
ROTATIONAL SCANNER SYSTEM

I. ULTRASONIC METHOD USING THE SA-ALC 360 DEGREE ROTATIONAL SCANNER SYSTEM.

II. DESCRIPTION OF SYSTEM. (See figure 1.)

The Rotational Scanner System is used to inspect fastener holes for radial cracks without removing the fasteners. It consists of a manual scanner head assembly, a transducer assembly, and accessories, and an ultrasonic reflectoscope.

a. The scanner head assembly consists of: three adjustable legs, a centering device for positioning the assembly on a fastener head, an adjustable transducer holder, and a transducer assembly. The transducer holder is adjustable for alignment of the transducer sound beam to the edge of a hole. The holder can be adjusted in three directions; tangential, radial, and angular. These adjustments allow the operator to direct a shear wave to the base of a countersink. The tangential adjustment moves the transducer assembly toward and away from a fastener hole. The radial adjustment moves the transducer assembly to right or left of a fastener hole. The angle is adjustable using a template to set it at the desired angle for sound entry into a part. This adjustment, once it is set, is fixed and cannot be continuously adjusted to maximize the signal response.

b. The transducer assembly consists of a transducer, a transducer sleeve, water and a flexible boot. The transducer assembly screws into the transducer holder. A water column, confined by means of the transducer, transducer sleeve and flexible boot, transmits sound through the rubber boot to the test piece.

c. The reflectoscope (figure 2) used in conjunction with the manual scanner head assembly is Automation Industries P/N UM775D with an AGIFM Timer and a 10NRF-VDB Pulser/Receiver. The gate and alarm for the Reflectoscope are on the internal panel. Access to this panel is gained by turning the lock counterclockwise and pulling the drawer out.

III. FUNCTION OF CONTROLS. (See figure 2.)

a. PULSER RECEIVER CONTROLS:

1. PULSE LENGTH control. This control is used to adjust the time duration of the high frequency pulse applied to the transducer. It should be adjusted for maximum signal return while maintaining required resolution. (Normally it is left near minimum and increased only to gain signal strength when maximum sensitivity does not suffice; excessive pulse length can obscure signals from defects close to the test surface.)

2. PULSE TUNING control This control is a capacitive adjustment which compensates for slight variations in distributed capacitance and other characteristics between cables and transducers. Depending on the requirements of the test situation, it should be adjusted to produce either the largest or most distinct indications.

3. REJECT control. This control is used to block the passage of low level irrelevant signals and noise signals for a clean CRT presentation which permits easier interpretation of echo signals.

4. FREQUENCY switch. This switch is used to select the operating frequency desired. The selected frequency normally corresponds to the operating frequency of the transducer being used.

5. VIDEO/RF switch. This switch is used to select one of two CRT display modes, either detected video or RF.

6. TEST THRU/NORMAL switch. This two-position switch is used to select one of two possible test modes. In the THRU position, two transducers are used; one transmits the high frequency pulse to the test specimen, the other receives the signals from the test specimen and sends pulses to the RF amplifier via the RECEIVER jack. In the NORMAL position, only one transducer is used and this transducer functions as the transmitter and receiver of the high frequency pulse.

7. SENSITIVITY controls. Three controls are provided to adjust the gain of the RF amplifier. A three-position slide switch allows coarse selection of three levels of gain: 0, 20, 40 dB. A stepped rotary switch permits fine adjustments in 2 dB steps (from 0 to 20 dB) within the gain level selected. A toggle switch marked 0 and 1 allows further fine adjustment of 1 dB, when needed. An additional screwdriver control marked CAL may be used to adjust the gain in a continuous manner (within approximately a 20 dB range) if desired. This is useful for aligning an echo on a certain graticule line during setup.)

8. R (RECEIVER) connector. The left receptacle marked R is used under the following conditions:

   (a) When testing in the pulse-echo mode (one transducer used and TEST switch set at NORMAL; using quartz or lithium sulfate transducers with short cable).

   (b) When testing in the through transmission mode (two transducers used and TEST switch set at THRU). Receiving transducer cable is connected to R receptacle.

9. T (TRANSMITTER) connector. The right receptacle marked T is used under the following conditions:

(a) When testing in the pulse-echo mode (one transducer) and using barium titanite, lead zirconate, or lead metaniobate types, or when cable is longer than 6 feet, 4 inches.

(b) When testing in the through (THRU) transmission mode with transmitting transducer cable connected to T receptacle.

b. AGIFM TIMER CONTROLS.

1. Front Panel Control Groups:

(a) Horizontal delay controls give coarse, fine and stepped control over sweep delay. This enables working over a great range of material thickness.

(b) The time or rate controls give coarse, fine and stepped control over the CRT sweep speed and thereby the relative expansion/contraction of the horizontal viewing time scale; i.e., horizontal signal magnification and/or calibration for different materials.

(c) The marker group gives coarse, fine and stepped control over pulse repetition frequency of the square wave marker scale. It is also possible to shift the markers independently with regard to horizontal position.

(d) Vertical, alternate, horizontal, and marker shift controls displace the CRT trace independently of any time related function.

2. Front Panel Controls:

(a) DELAY (CRS). Coarse control over the duration of sweep delay. (Delay enables the operator to center signals regardless of thickness of material.)

(b) DELAY (FINE). Vernier control over the duration of sweep delay. (MAX-MIN rotational directions are indicated on controls (a) and (b) above.)

(c) SWEEP DELAY MICROSECONDS. Gives three step control over sweep delay from 0 to 500 microseconds.

(d) SWEEP (CRS). Controls the duration of the sweep pulse. (Sweep rate enables the horizontal expansion/contraction of displayed waveforms and calibration against the graticule system.)

(e) SWEEP (MATL). Varies horizontal calibration to compensate for propagation velocity of materials.

(f) SWEEP RANGE INCHES/DIV. Gives five step controls over sweep range from .02 to 10 inches/division.

(g) MODE (SHEAR). Compensates for difference between longitudinal and shear velocity in steel.

(h) VERTICAL and HORIZ. Displaces primary trace position. ALTN displaces marker baseline along the vertical axis.

(i) RATE. Controls the basic pulse repetition rate of the timer circuitry. (100 to 200 Hz)

(j) MARKER RANGE CRS. Turns marker function "on" and may be set to three stepped ranges of marker repetition rates.

(k) MARKER RANGE FINE. Fine adjustment of marker repetition rate.

(l) MARKER SHIFT. Adjusts horizontal position of marker trace.

3. Internal Panel Controls:
(See figure 3.)

(a) GATE START (FINE). Varies time constant of gate start circuit by varying R/C network resistance.

(b) GATE START (CRS). Varies time constant of gate start circuit by large R/C capacitor steps.

(c) GATE LENGTH (FINE). Varies time constant of gate length circuit by varying R/C network resistance.

(d) GATE LENGTH (CRS). Varies time constant of gate length circuit large R/C capacitor steps.

(e) IF SYNC. Enable/defeat IF sync function. A three position switch synchronizes time of start of gate and sweep to compensate for variations in length of water path in immersion testing.

(1) IF SYNC-GATE SWP. Gate and sweep are started by first video signal (interface).

(2) IF SYNC-GATE. Gate only is started by interface signal.

(3) IF SYNC-OFF. Interface synchronization capability disabled. Cate is started from "main sync" time and sweep is started after sweep delay.

(f) GATE ON-OFF. Enable/defeat gate function.

(g) AURAL ON-OFF. Enable/defeat auditory alarm.

(h) ALARM POLARITY $\pm$. Alarm on + or - video signal.

(i) ALARM LEVEL. Sets video level at which alarm signal is activated.

c. DISPLAY CHASSIS CONTROLS. (See figure 2.)

1. Display Chassis Controls. The operator controls located on the display chassis are the power switch, astigmatism, intensity, and focus controls. The last three controls are screwdriver adjustable because, once set for optimum conditions, they do not usually require readjustment.

2. Functions of Controls:

(a) POWER switch. This switch is pressed once to turn Reflectoscope power on, and pressed again to turn power off. When power is on, the switch is illuminated.

(b) ASTIG (Astigmatism). Screwdriver adjusted control which corrects for distortion of the CRT trace. Used in conjunction with the FOCUS control to obtain sharpest trace line.

(c) FOCUS. Screwdriver adjusted control which is adjusted to obtain the sharpest trace line.

(d) INTENSITY. Screwdriver adjusted control for adjusting the brightness of the CRT trace. Adjustment of the INTENSITY control usually necessitates a readjustment of the FOCUS and ASTIG controls to return the trace to its sharpest appearance.

IV. NDI PROCEDURE NO. 2 - ULTRASONIC.

a. NDI equipment:

(1) Reflectoscope, Automation Industries, P/N UM775D.

(2) Transducer, 10 MHz, 3/16 dia., longitudinal wave, P/N SPO-574, 2 required.

(3) Cable, 12 foot, 90 degree, Microdot/UHF Connector Sperry P/N 57A2270, 2 required.

(4) Video Plug-In Module 10NRF-VDB.

(5) Couplant, light oil.

(6) Calibration Standard, as illustrated.

(7) SA-ALC 360 Degree Scanner Head Assembly.

(8) 26 Degree Template.

b. Access: The exterior skin surface where inspections are to be performed is readily accessible.

c. Preparation of Part: Clean local inspection areas as required to permit good contact between part and transducer.

d. Assembly:

(1) Assemble the transducers and sleeves as illustrated. (See figure 4.)

(2) Screw the transducer/sleeve assembly into the transducer holding fixture.

(3) Using the 26 degree template, set the transducers to an angle of 26 degrees. This can be accomplished by loosening the allen screw that secures the holder in position, then set the holder to the 26 degree angle and tighten the allen screw. (See figure 5.)

(4) Place the scanning head assembly on the standard (figure 6), and adjust the three scanner legs to provide an acceptable and uniform boot contact pressure. (See figure 7.)

(5) Connect the transducer cables to the transducers and to the "T" Receptacle of the UM775D Reflectoscope.

e. Instrument settings/calibration:

(1) Depress the Reflectoscope power switch to the ON position and allow the unit to warm up for five minutes.

(2) Adjust the Reflectoscope to the following preliminary settings:

(a)	Sweep Delay	0 - 5
(b)	MODE	SHEAR
(c)	SWEEP RANGE	.1
(d)	PULSE LENGTH	Max (Full CW)
(e)	PULSE TUNING	Max (Full CW)
(f)	REJECT	1/3 Turn CW
(g)	RF/VIDEO Switch	VIDEO
(h)	TEST Switch	NORMAL
(i)	Frequency	10.0 MHz
(j)	DB Switch	0
(k)	DB Knob	18

(3) Place the Scanner Head Assembly on the standard with the center positioner in the fastener hole with the fastener removed. (See figure 6.)

NOTE

Only one transducer can be activated at a time.

(4) Position the switch to activate one of the two transducers.

(5) Using the radial adjustment knob, position the C/L of the activated transducer to align with the C/L of the fastener hole which has the sawcut. (See figure 8.)

(6) Adjust the tangential adjustment knob until a back reflection from the fastener hole appears on the CRT screen. (See figure 9.)

(7) Maximize the signal from the fastener hole using both the tangential and radial adjustment knobs.

(8) Using the sweep and delay controls, position the initial pulse near the left hand side of the CRT screen and the back reflection from the fastener hole near the center of the CRT screen. (See figure 9.)

(9) Rotate the transducer until the sound path is 90 degrees to the radial direction of the sawcut. (See figure 8.)

(10) Using the radial direction knob adjust the transducer until it is aligned with the sawcut.

(11) Using the tangential knob, move the transducer towards the sawcut until an indication from the sawcut appears on the CRT screen. (See figures 8 and 9.)

(12) Using the tangential and radial direction knobs, maximize the back reflection from the sawcut.

(13) With the sawcut back reflection maximized, adjust the Reflectoscope sensitivity to give 80 percent of scope saturation from the sawcut.

(14) Loosen the lock and pull out the internal panel containing the gate controls. (See figure 3.)

(15) Set the gate controls to the following settings: (See figuure 3.)

(a)	IF SYNC	OFF
(b)	AURAL	ON
(c)	GATE	ON
(d)	ALARM POLARITY	+
(e)	GATE LENGTH CRS	2
(f)	GATE START CRS	2
(g)	GATE LENGTH FINE	Set to approx. 1/2 inch in length
(h)	GATE START FINE	Move the Gate to the indication from the sawcut. (See figure 8.)
(i)	ALARM LEVEL	Set the alarm level so that it will be activated when the back reflection from the sawcut reaches the 50 percent level of scope saturation.

(16) Rotate the transducer 360 degrees and note the CRT presentation and gate.

(17) The back reflection from the sawcut represents a defect.

(18) To calibrate for the second transducer, position the switch to activate it and position the transducer so that the sound path will hit the sawcut from the opposite direction of the first transducer. (See figure 8.)

(19) Repeat steps (5) through (16) for the second transducer.

f. Inspection

(1) With the Scanning System properly calibrated, apply couplant to the practice panel and inspect all accessible fastener holes with both transducers. (See figure 10.)

g. Mark and report indicated defects.

SELF INTRODUCTION FOR THE ULTRASONIC SA-ALC 360 DEGREE
ROTATIONAL SCANNER SYSTEM

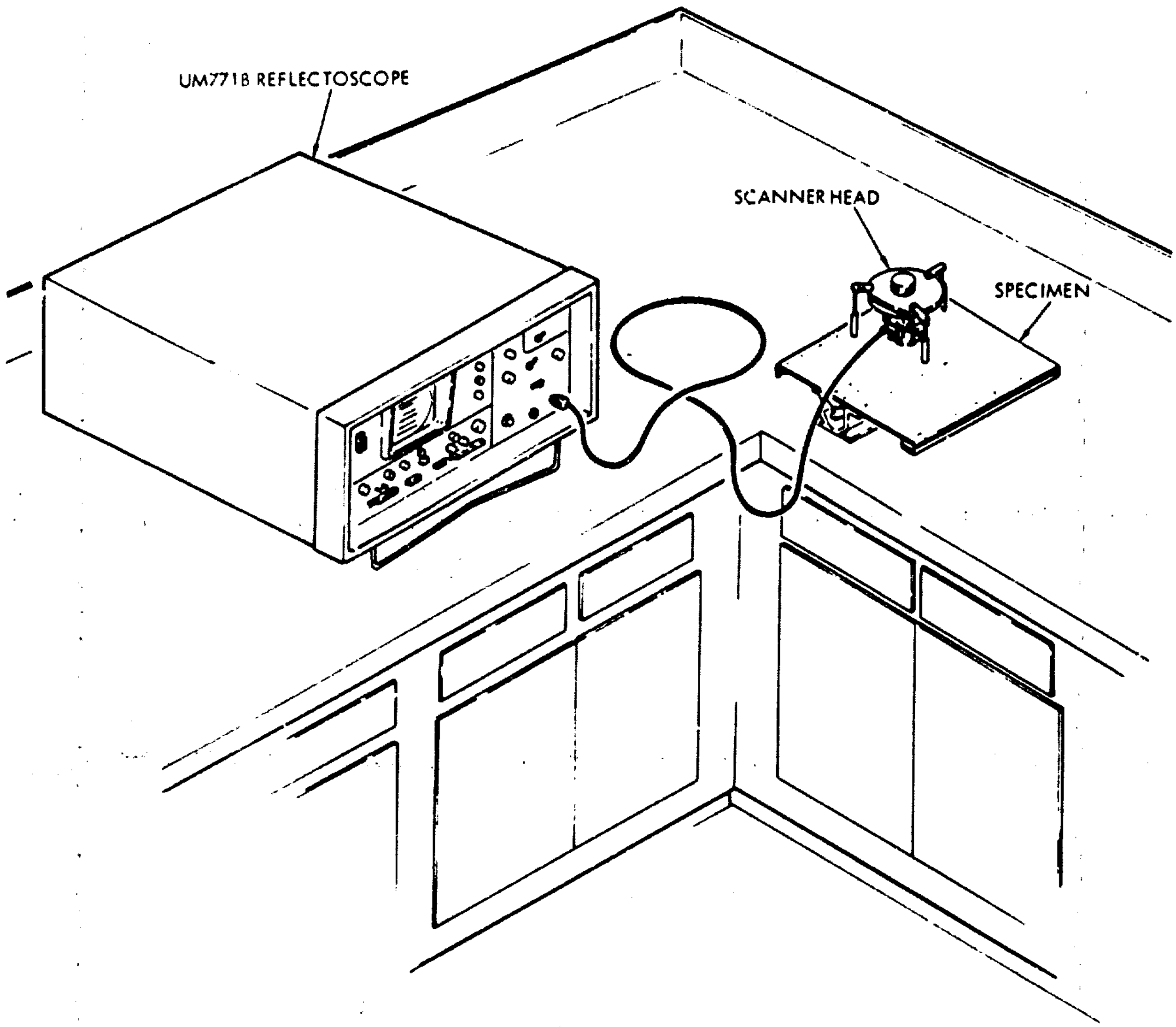


Figure 1. The Ultrasonic SA-ALC 360 Degree Rotational Scanner System

SELF INTRODUCTION FOR THE ULTRASONIC SA-ALC 360 DEGREE ROTATIONAL SCANNER SYSTEM

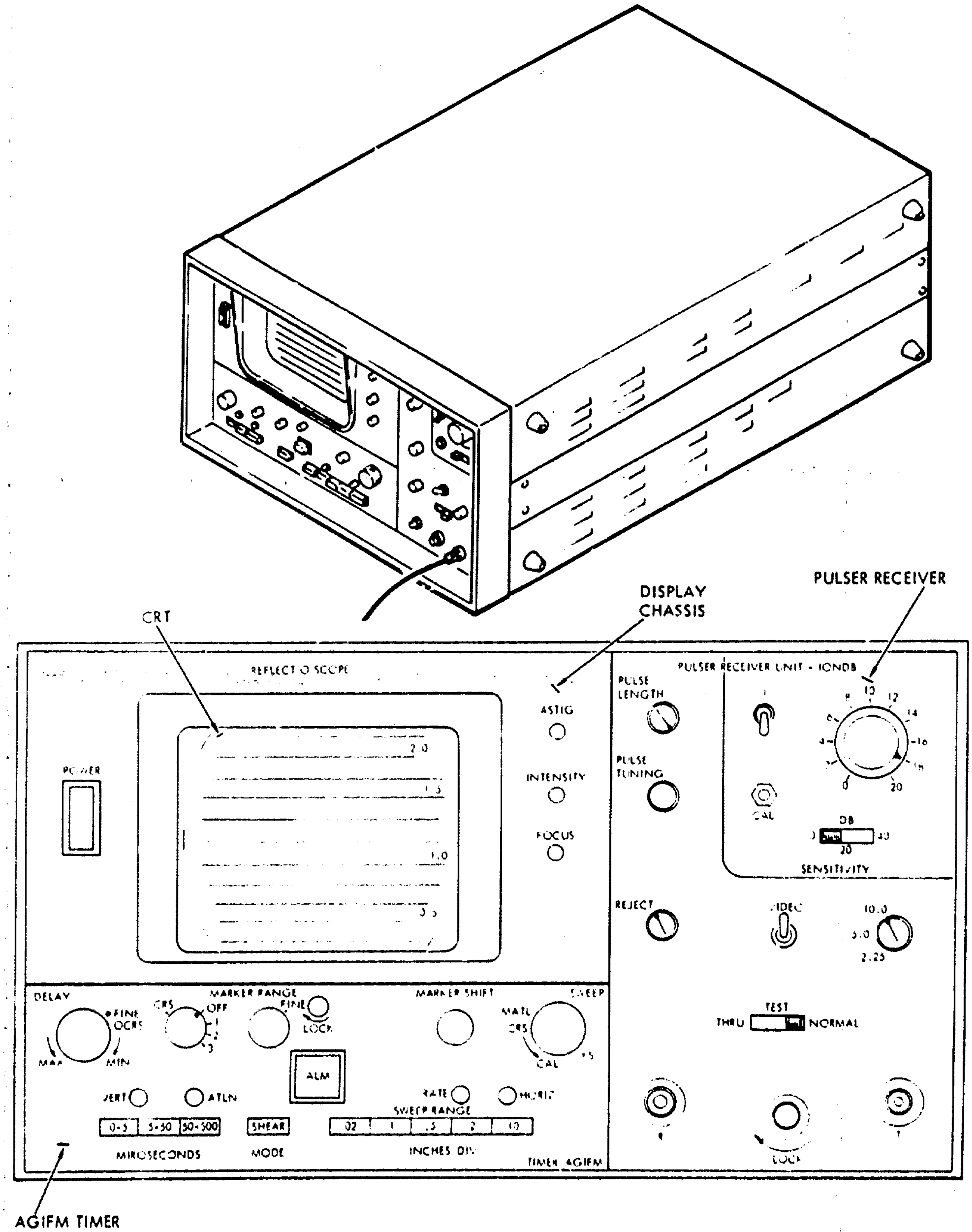
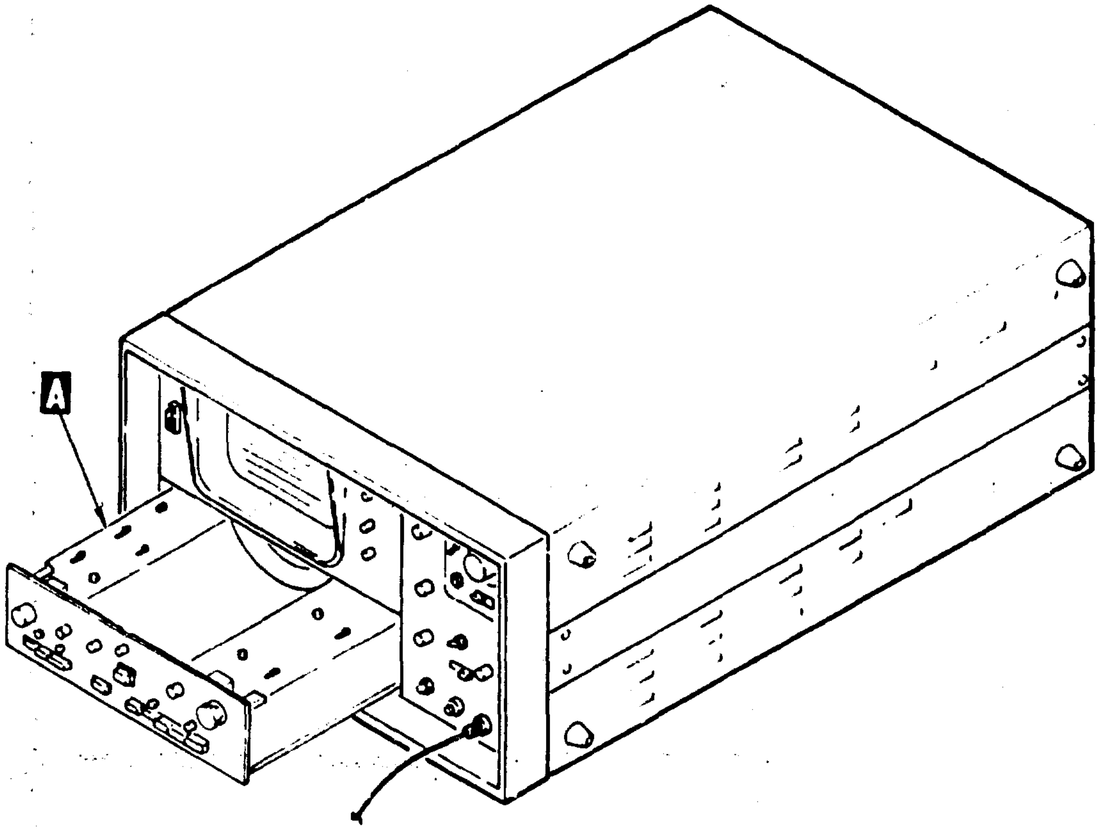


Figure 2. The Reflectoscope

SELF INTRODUCTION FOR THE ULTRASONIC SA-ALC 360 DEGREE ROTATIONAL SCANNER SYSTEM



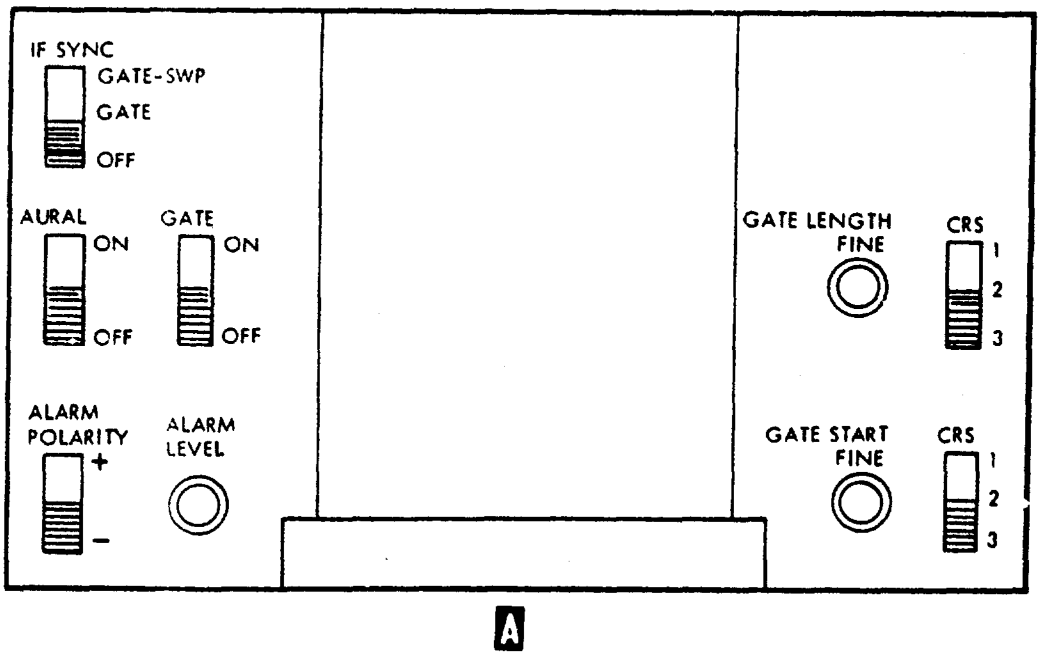
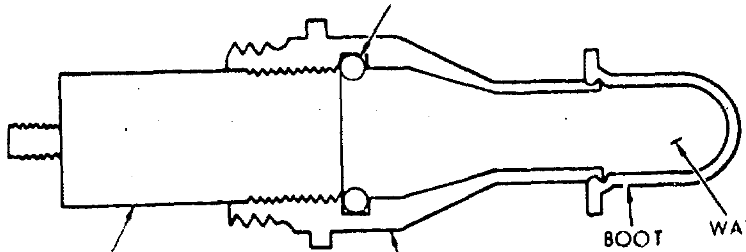


Figure 3. Reflectoscope Internal Panel Controls



TRANSDUCER ASSEMBLY

NOTE

1. ASSEMBLE WITH TRANSDUCER SLEEVE AND BOOT UNDER WATER. USE DEAERATED WATER OR WATER THAT HAS BEEN ALLOWED TO STAND FOR 24 HOURS AT ROOM TEMPERATURE, TO PREVENT AIR BUBBLES FROM FORMING INSIDE THE ASSEMBLY. DURING ASSEMBLY, REMOVE BUBBLES FROM THREADED END OF TRANSDUCER AND FROM INSIDE THE SLEEVE AND BOOT.
2. THREAD TRANSDUCER HALF WAY INTO SLEEVE.
3. SLIP BOOT ON END OF SLEEVE AND SEAT BOOT RIM IN SLEEVE GROOVE.
4. COMPLETE THREADING OF TRANSDUCER INTO SLEEVE UNTIL IT SEATS AGAINST "O" RING.

Figure 4. Transducer Assembly

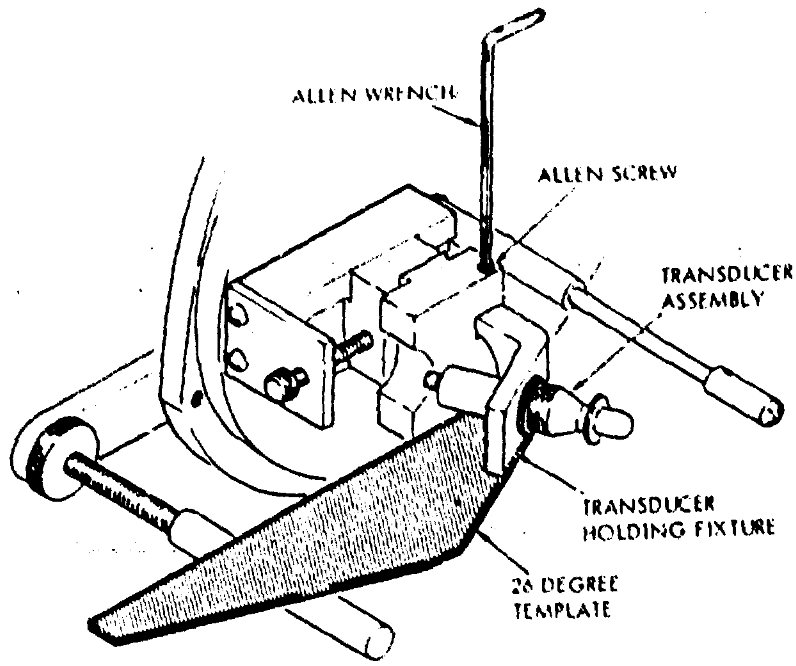


Figure 5. Installation of Transducer Assembly

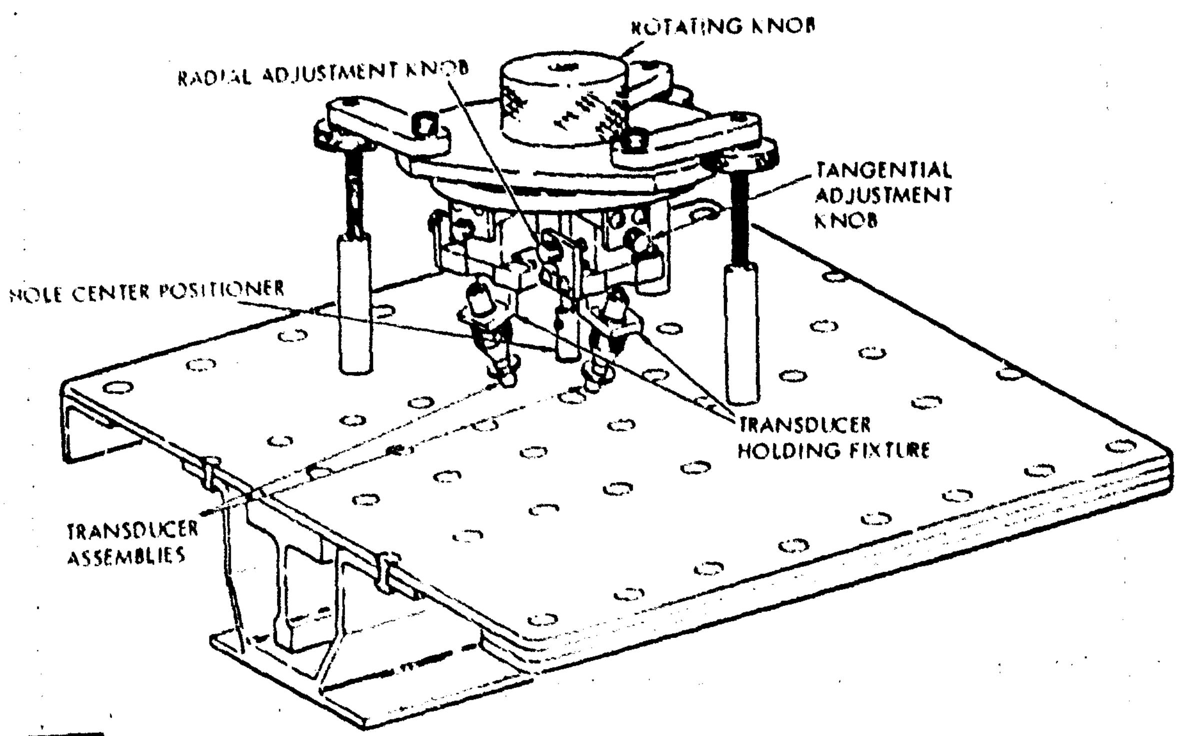


Figure 6. Positioning and Adjustment of Scanning Head Assembly

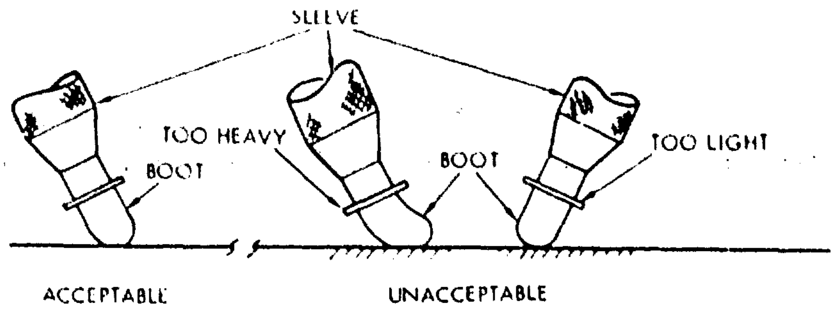


Figure 7. Transducer Boot Contact Pressure

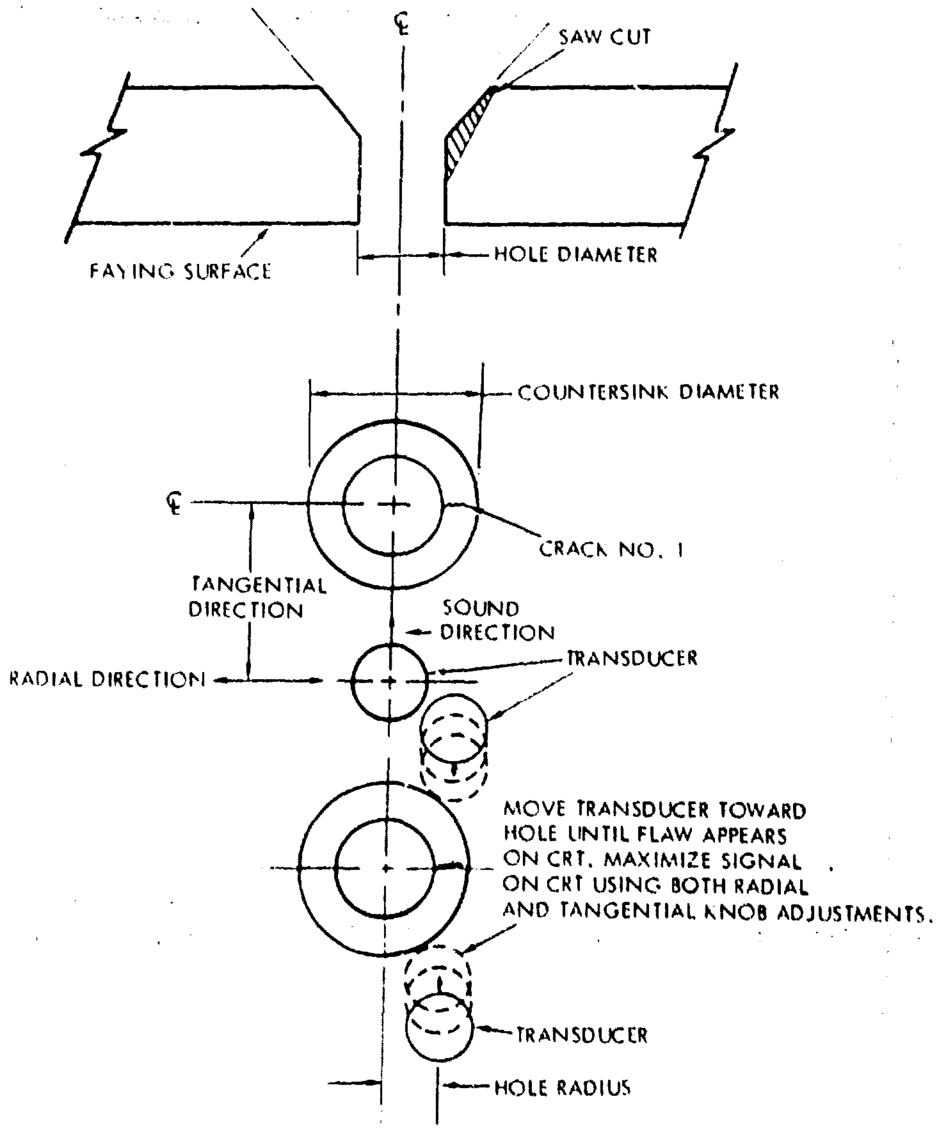


Figure 8. Alignment of Scanning Head Assembly to Hole

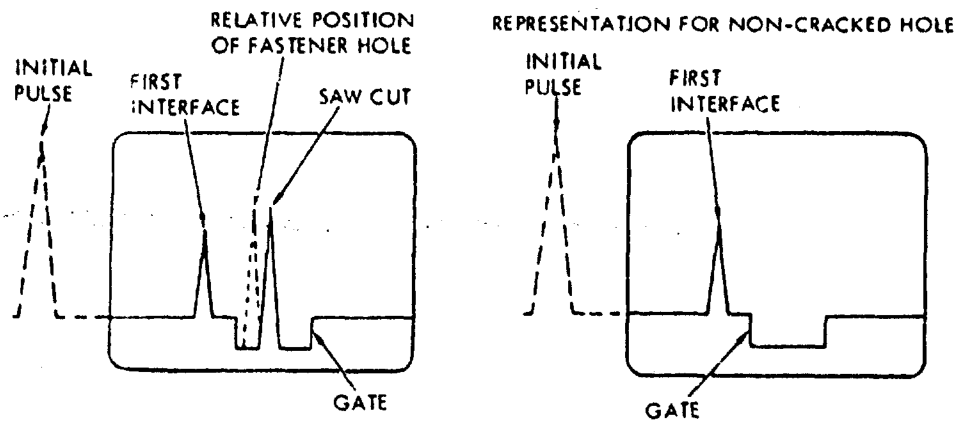


Figure 9. CRT Presentation

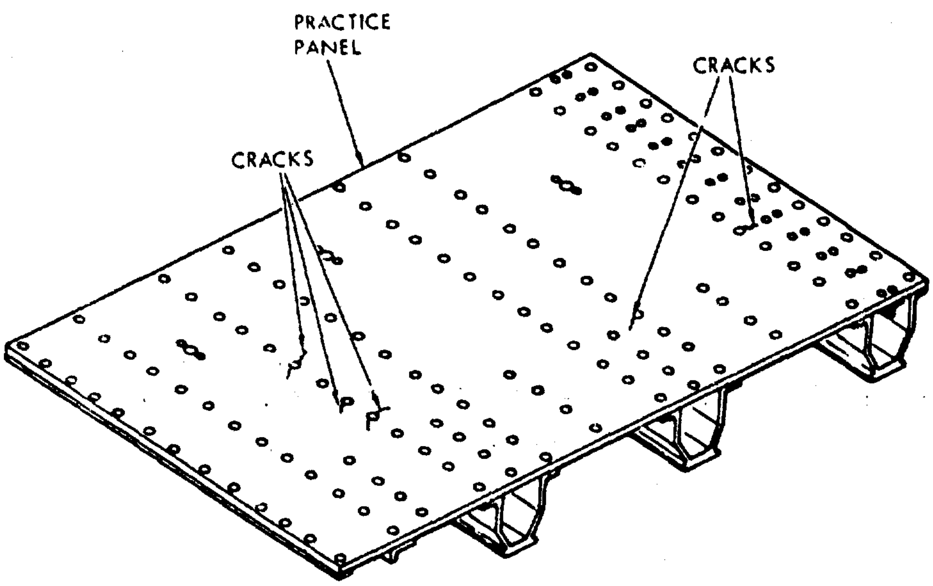


Figure 10. Practice Panel

OPERATIONAL SUPPLEMENT NO. 2

TECHNICAL MANUAL

NONDESTRUCTIVE INSPECTION

RELIABILITY PROGRAM

THIS PUBLICATION SUPPLEMENTS TECHNICAL MANUAL NONDESTRUCTIVE INSPECTION, RELIABILITY PROGRAM. Reference to this supplement will be made on the title page of the basic publication by personnel responsible for maintaining the publication in current status.

15 DECEMBER 1976

1. PURPOSE.

The purpose of this supplement is to add procedures for operation of new NDI equipment, the SA-ALC 360 Degree Rotational Scanner System.

2. INSTRUCTIONS.

A. On page 1-1, add the following entry to the table of contents immediately following the FLAW DETECTOR EQUIVALENCY listing.

B. On page 1-19, add the following paragraphs and figures 1-11, 1-12, and 1-13 immediately following table 1-III.

1-21A. <u>ULTRASONIC METHOD USING THE SA-ALC 360 DEGREE ROTATIONAL SCANNER SYSTEM.</u>

1-21B. DESCRIPTION OF SYSTEM. (See figure 1-11.)

The Rotational Scanner System is used to inspect fastener holes for radial cracks without removing the fasteners. It consists of a manual scanner head assembly, a transducer assembly, and accessories, and an ultrasonic reflectoscope.

a. The scanner head assembly consists of: three adjustable legs, a centering device for positioning the assembly on a fastener head, an adjustable transducer holder, and a transducer assembly. The transducer holder is adjustable for alignment of the transducer sound beam to the edge of a hole. The holder can be adjusted in three directions; tangential, radial, and angular. These adjustments allow the operator to direct a shear wave to the base of a countersink. The tangential adjustment moves the transducer assembly toward and away from a fastener hole. The radial adjustment moves the transducer assembly to right or left of a fastener hole. The angle is adjustable using a template to set it at the desired angle for sound entry into a part. This adjustment, once it is set, is fixed and cannot be continuously adjusted to maximize the signal response.

b. The transducer assembly consists of a transducer, a transducer sleeve, water and a flexible boot. The transducer assembly screws into the transducer holder. A water column, confined by means of the transducer, transducer sleeve and flexible boot, transmits sound through the rubber boot to the test piece.

c. The reflectoscope (figure 1-12) used in conjunction with the manual scanner head assembly is Automation Industries P/N UM775D with an AGIFM Timer and a 10NRF-VDB Pulser/Receiver. The gate and alarm for the Reflectoscope are on the internal panel. Access to this panel is gained by turning the lock counterclockwise and pulling the drawer out.

1-21C. FUNCTION OF CONTROLS. (See figure 1-12.)

a. PULSER RECEIVER CONTROLS:

1. PULSE LENGTH control. This control is used to adjust the time duration of the high frequency pulse applied to the transducer. It should be adjusted for maximum signal return while maintaining required resolution. (Normally it is left near minimum and increased only to gain signal strength when maximum sensitivity does not suffice; excessive pulse length can obscure signals from defects close to the test surface.)

2. PULSE TUNING control. This control is a capacitive adjustment which compensates for slight variations in distributed capacitance and other characteristics between cables and transducers. Depending on the requirements of the test situation, it should be adjusted to produce either the largest or most distinct indications.

3. REJECT control. This control is used to block the passage of low level irrelevant signals and noise signals for a clean CRT presentation which permits easier interpretation of echo signals.

4. FREQUENCY switch. This switch is used to select the operating frequency desired. The selected frequency normally corresponds to the operating frequency of the transducer being used.

5. VIDEO/RF switch. This switch is used to select one of two CRT display modes, either detected video or RF.

6. TEST THRU/NORMAL switch. This two-position switch is used to select one of two possible test modes. In the THRU position, two transducers are used; one transmits the high frequency pulse to the test specimen, the other receives the signals from the test specimen and sends pulses to the RF amplifier via the RECEIVER jack. In the NORMAL position, only one transducer is used and this transducer functions as the transmitter and receiver of the high frequency pulse.

7. SENSITIVITY controls. Three controls are provided to adjust the gain of the RF amplifier. A three-position slide switch allows coarse selection of three levels of gain: 0, 20, 40 dB. A stepped rotary switch permits fine adjustments in 2 dB steps (from 0 to 20 dB) within the gain level selected. A toggle switch marked 0 and 1 allows further fine adjustment of 1 dB, when needed. An additional screwdriver control marked CAL may be used to adjust the gain in a continuous manner (within approximately a 20 dB range) if desired. This is useful for aligning an echo on a certain graticule line during setup.)

8. R (RECEIVER) connector. The left receptacle marked R is used under the following conditions:

   (a) When testing in the pulse-echo mode (one transducer used and TEST switch set at NORMAL; using quartz or lithium sulfate transducers with short cable).

   (b) When testing in the through transmission mode (two transducers used and TEST switch set at THRU). Receiving transducer cable is connected to R receptacle.

9. T (TRANSMITTER) connector. The right receptacle marked T is used under the following conditions:

   (a) When testing in the pulse-echo mode (one transducer) and using barium titanite, lead zirconate, or lead metaniobate types, or when cable is longer than 6 feet, 4 inches.

   (b) When testing in the through (THRU) transmission mode with transmitting transducer cable connected to T receptacle.

b. AGIFM TIMER CONTROLS.

1. Front Panel Control Groups:

(a) Horizontal delay controls give coarse, fine and stepped control over sweep delay. This enables working over a great range of material thickness.

(b) The time or rate controls give coarse, fine and stepped control over the CRT sweep speed and thereby the relative expansion/contraction of the horizontal viewing time scale; i.e., horizontal signal magnification and/or calibration for different materials.

(c) The marker group gives coarse, fine and stepped control over pulse repetition frequency of the square wave marker scale. It is also possible to shift the markers independently with regard to horizontal position.

(d) Vertical, alternate, horizontal, and marker shift controls displace the CRT trace independently of any time related function.

2. Front Panel Controls:

(a) DELAY (CRS). Coarse control over the duration of sweep delay. (Delay enables the operator to center signals regardless of thickness of material.)

(b) DELAY (FINE). Vernier control over the duration of sweep delay. (MAX-MIN rotational directions are indicated on controls (a) and (b) above.)

(c) SWEEP DELAY MICROSECONDS. Gives three step control over sweep delay from 0 to 500 microseconds.

(d) SWEEP (CRS). Controls the duration of the sweep pulse. (Sweep rate enables the horizontal expansion/contraction of displayed waveforms and calibration against the graticule system.)

(e) SWEEP (MATL). Varies horizontal calibration to compensate for propagation velocity of materials.

(f) SWEEP RANGE INCHES/DIV. Gives five step controls over sweep range from .02 to 10 inches/division.

(g) MODE (SHEAR). Compensates for difference between longitudinal and shear velocity in steel.

(h) VERTICAL and HORIZ. Displaces primary trace position. ALTN displaces marker baseline along the vertical axis.

(i) RATE. Controls the basic pulse repetition rate of the timer circuitry. (100 to 200 Hz)

(j) MARKER RANGE CRS. Turns marker function "on" and may be set to three stepped ranges of marker repetition rates.

(k) MARKER RANGE FINE. Fine adjustment of marker repetition rate.

(l) MARKER SHIFT. Adjusts horizontal position of marker trace.

3. Internal Panel Controls:
(See figure 1-13.)

(a) GATE START (FINE). Varies time constant of gate start circuit by varying R/C network resistance.

(b) GATE START (CRS). Varies time constant of gate start circuit by large R/C capacitor steps.

(c) GATE LENGTH (FINE). Varies time constant of gate length circuit by varying R/C network resistance.

(d) GATE LENGTH (CRS). Varies time constant of gate length circuit large R/C capacitor steps.

(e) IF SYNC. Enable/defeat IF sync function. A three position switch synchronizes time of start of gate and sweep to compensate for variations in length of water path in immersion testing.

(1) IF SYNC-GATE SWP. Gate and sweep are started by first video signal (interface).

(2) IF SYNC-GATE. Gate only is started by interface signal.

(3) IF SYNC-OFF. Interface synchronization capability disabled. Gate is started from "main sync" time and sweep is started after sweep delay.

(f) GATE ON-OFF. Enable/defeat gate function.

(g) AURAL ON-OFF. Enable/defeat auditory alarm.

(h) ALARM POLARITY ±. Alarm on + or - video signal.

(i) ALARM LEVEL. Sets video level at which alarm signal is activated.

c. DISPLAY CHASSIS CONTROLS. (See figure 1-12.)

1. Display Chassis Controls. The operator controls located on the display chassis are the power switch, astigmatism, intensity, and focus controls. The last three controls are screwdriver adjustable because, once set for optimum conditions, they do not usually require readjustment.

2. Functions of Controls:

(a) POWER switch. This switch is pressed once to turn Reflectoscope power on, and pressed again to turn power off. When power is on, the switch is illuminated.

(b) ASTIG (Astigmatism). Screwdriver adjusted control which corrects for distortion of the CRT trace. Used in conjunction with the FOCUS control to obtain sharpest trace line.

(c) FOCUS. Screwdriver adjusted control which is adjusted to obtain the sharpest trace line.

(d) INTENSITY. Screwdriver adjusted control for adjusting the brightness of the CRT trace. Adjustment of the INTENSITY control usually necessitates a readjustment of the FOCUS and ASTIG controls to return the trace to its sharpest appearance.

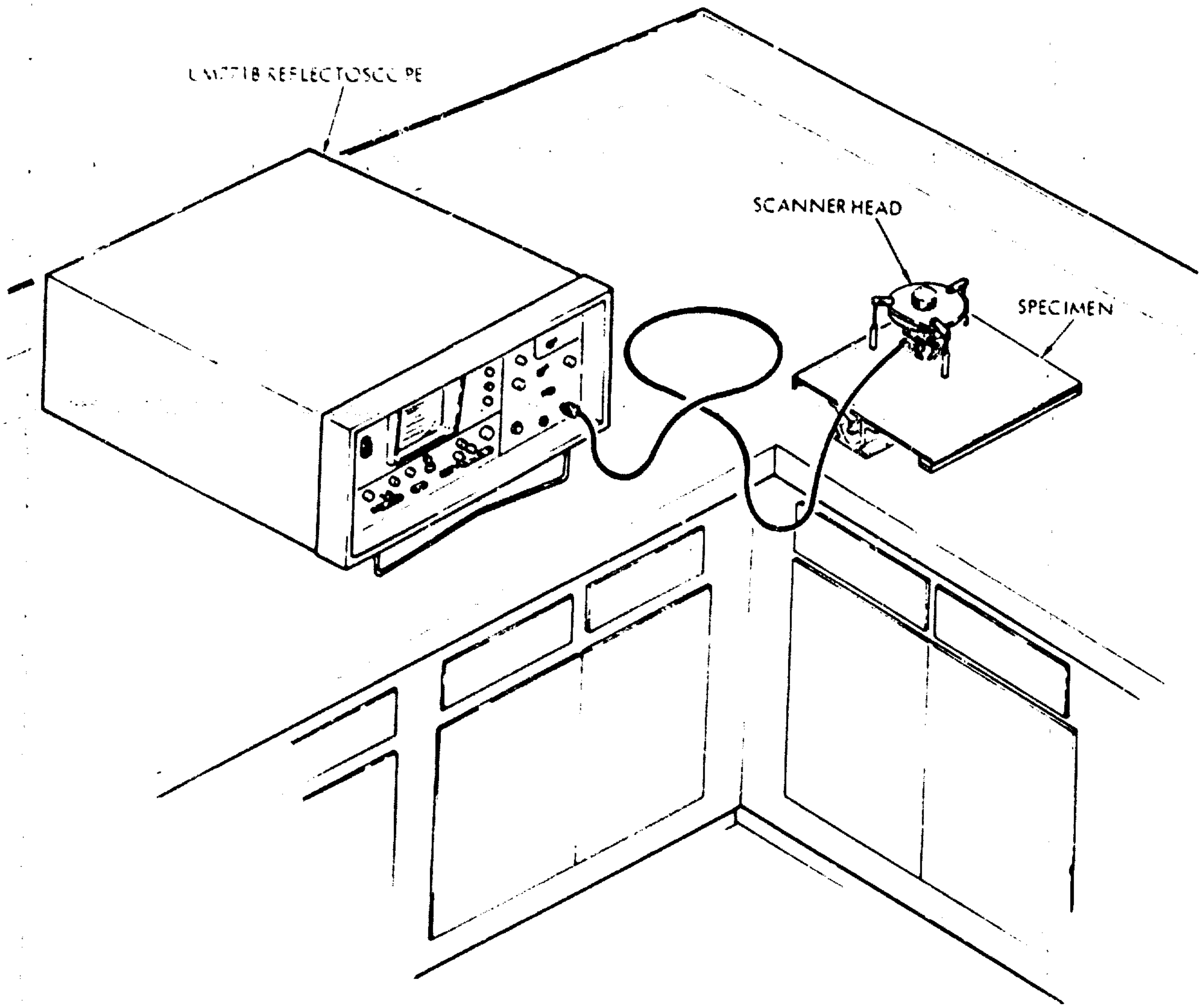


Figure 1-11. The Ultrasonic SA-ALC 360 Degree Rotational Scanner System

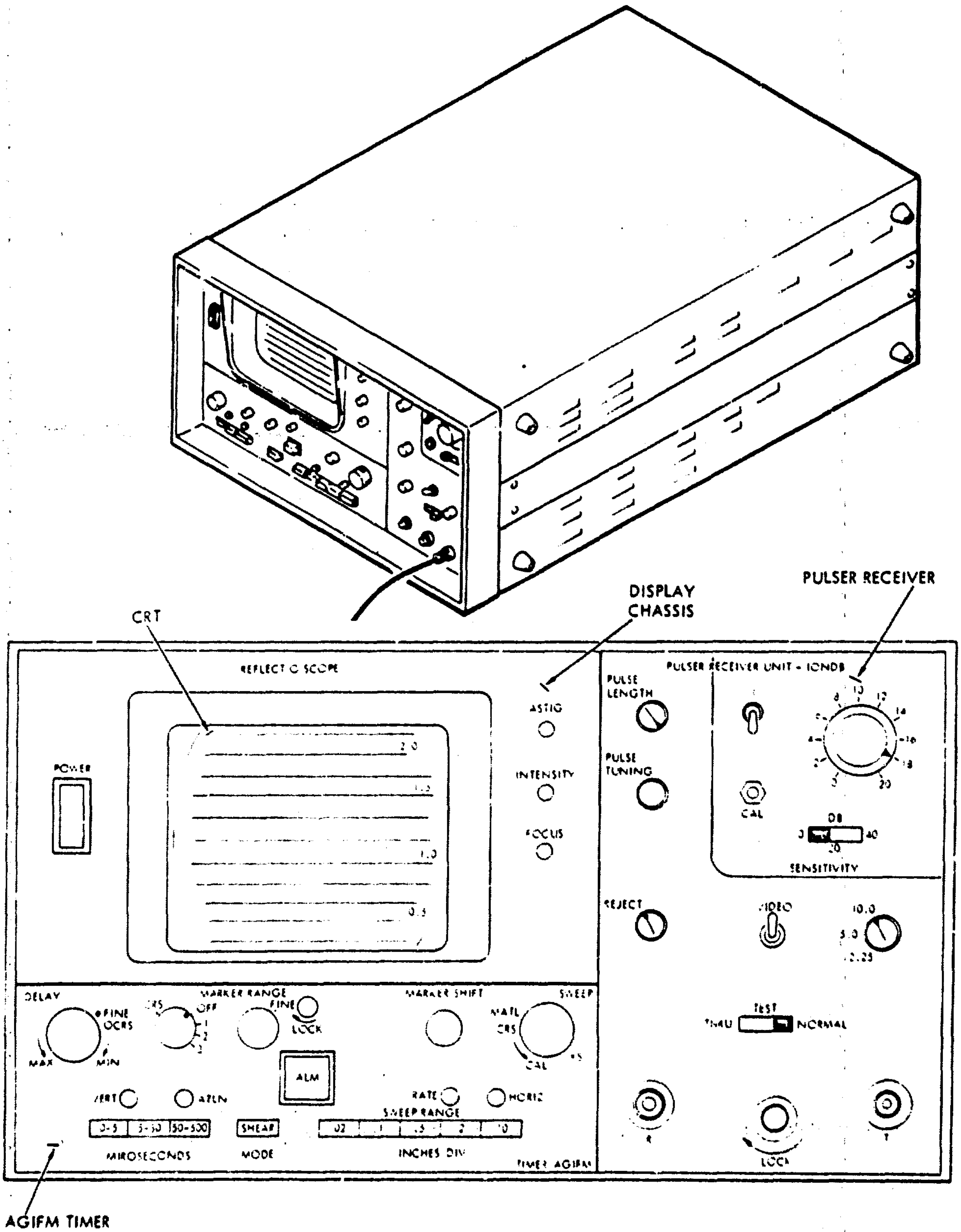
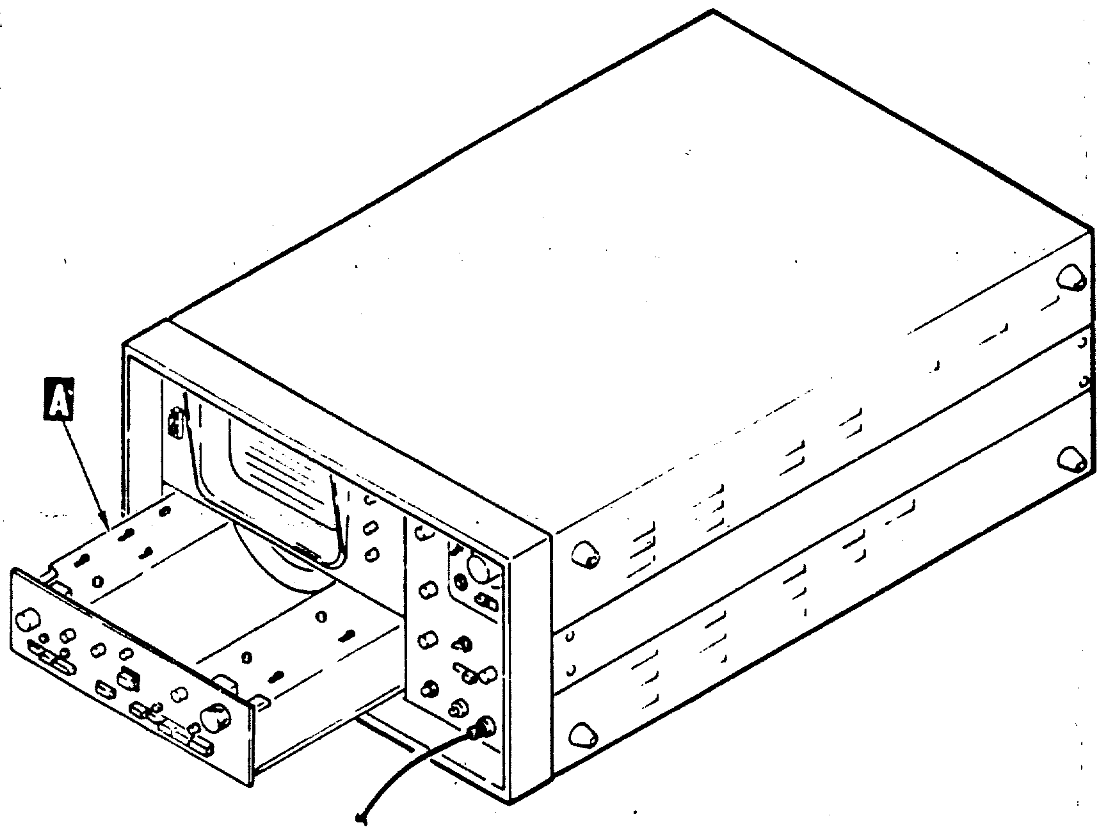


Figure 1-12. The Reflectoscope



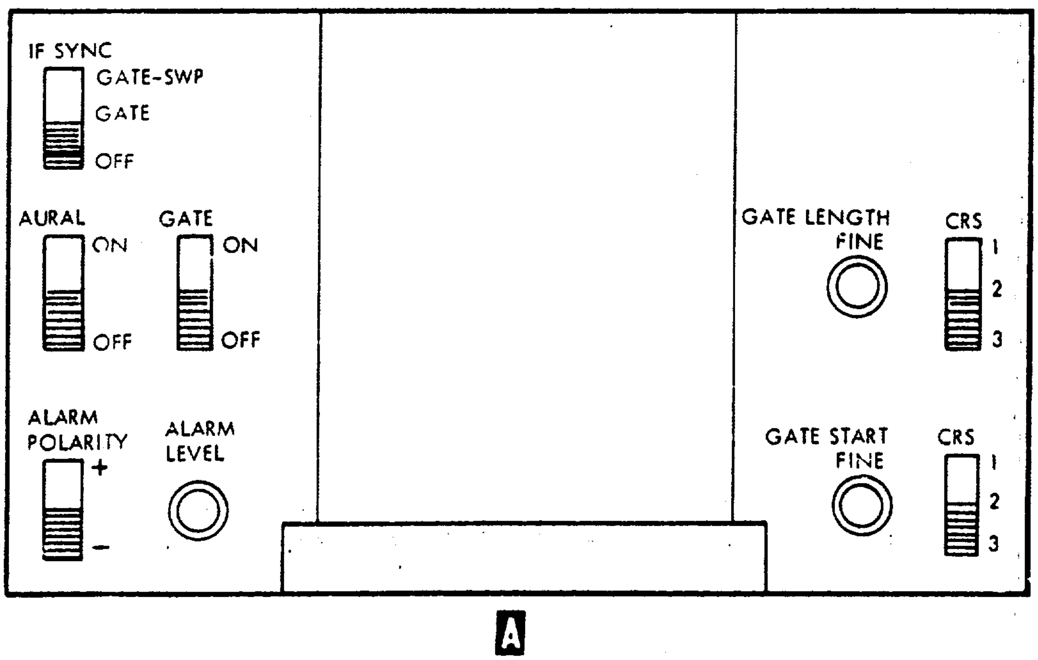


Figure 1-13. Reflectoscope Internal Panel Controls

C. On page 2-3, add the following procedure after NDI Procedure No. 1.

2-5A. NDI PROCEDURE NO. 2 - ULTRASONIC.

a. NDI equipment:

(1) Reflectoscope, Automation Industries, P/N UM775D.

(2) Transducer, 10 MHz, 3/16 dia., longitudinal wave, P/N SPO-574, 2 required.

(3) Cable, 12 foot, 90 degree, Microdot/UHF Connector Sperry P/N 57A2270, 2 required.

(4) Video Plug-In Module 10NRF-VDB.

(5) Couplant, light oil.

(6) Calibration Standard, as illustrated.

(7) SA-ALC 360 Degree Scanner Head Assembly.

(8) 26 Degree Template.

b. Access: The exterior skin surface where inspections are to be performed is readily accessible.

c. Preparation of Part: Clean local inspection areas as required to permit good contact between part and transducer.

d. Assembly:

(1) Assemble the transducers and sleeves as illustrated. (See figure 2-1A.)

(2) Screw the transducer/sleeve assembly into the transducer holding fixture.

(3) Using the 26 degree template, set the transducers to an angle of 26 degrees. This can be accomplished by loosening the allen screw that secures the holder in position, then set the holder to the 26 degree angle and tighten the allen screw. (See figure 2-1A.)

(4) Place the scanning head assembly on the standard (figure 2-1A), and adjust the three scanner legs to provide an acceptable and uniform boot contact pressure. (See figure 2-1A.)

(5) Connect the transducer cables to the transducers and to the "T" Receptacle of the UM775D Reflectoscope.

e. Instrument settings/calibration:

(1) Depress the Reflectoscope power switch to the ON position and allow the unit to warm up for five minutes.

(2) Adjust the Reflectoscope to the following preliminary settings:

(a)	Sweep Delay	0 - 5
(b)	MODE	SHEAR
(c)	SWEEP RANGE	.1
(d)	PULSE LENGTH	Max (Full CW)
(e)	PULSE TUNING	Max (Full CW)
(f)	REJECT	1/3 Turn CW
(g)	RF/VIDEO Switch	VIDEO
(h)	TEST Switch	NORMAL
(i)	Frequency	10.0 MHz
(j)	DB Switch	0
(k)	DB Knob	18

(3) Place the Scanner Head Assembly on the standard with the center positioner in the fastener hole with the fastener removed. (See figure 2-1A.)

NOTE

Only one transducer can be activated at a time.

(4) Position the switch to activate one of the two transducers.

(5) Using the radial adjustment knob, position the C/L of the activated transducer to align with the C/L of the fastener hole which has the sawcut. (See figure 2-1A.)

(6) Adjust the tangential adjustment knob until a back reflection from the fastener hole appears on the CRT screen. (See figure 2-1A.)

(7) Maximize the signal from the fastener hole using both the tangential and radial adjustment knobs.

(8) Using the sweep and delay controls, position the initial pulse near the left hand side of the CRT screen and the back reflection from the fastener hole near the center of the CRT screen. (See figure 2-1A.)

(9) Rotate the transducer until the sound path is 90 degrees to the radial direction of the sawcut. (See figure 2-1A.)

(10) Using the radial direction knob adjust the transducer until it is aligned with the sawcut.

(11) Using the tangential knob, move the transducer towards the sawcut until an indication from the sawcut appears on the CRT screen. (See figure 2-1A.)

(12) Using the tangential and radial direction knobs, maximize the back reflection from the sawcut.

(13) With the sawcut back reflection maximized, adjust the Reflectoscope sensitivity to give 80 percent of scope saturation from the sawcut.

(14) Loosen the lock and pull out the internal panel containing the gate controls. (See figure 1-13.)

(15) Set the gate controls to the following settings: (See figuure 1-13.)

(a)	IF SYNC	OFF
(b)	AURAL	ON
(c)	GATE	ON
(d)	ALARM POLARITY	+
(e)	GATE LENGTH CRS	2
(f)	GATE START CRS	2
(g)	GATE LENGTH FINE	Set to approx. 1/2 inch in length
(h)	GATE START FINE	Move the Gate to the indication from the sawcut. (See figure 2-1A.)
(i)	ALARM LEVEL	Set the alarm level so that it will be activated when the back reflection from the sawcut reaches the 50 percent level of scope saturation.

(16) Rotate the transducer 360 degrees and note the CRT presentation and gate.

(17) The back reflection from the sawcut represents a defect.

(18) To calibrate for the second transducer, position the switch to activate it and position the transducer so that the sound path will hit the sawcut from the opposite direction of the first transducer. (See figure 2-1A.)

(19) Repeat steps (5) through (16) for the second transducer.

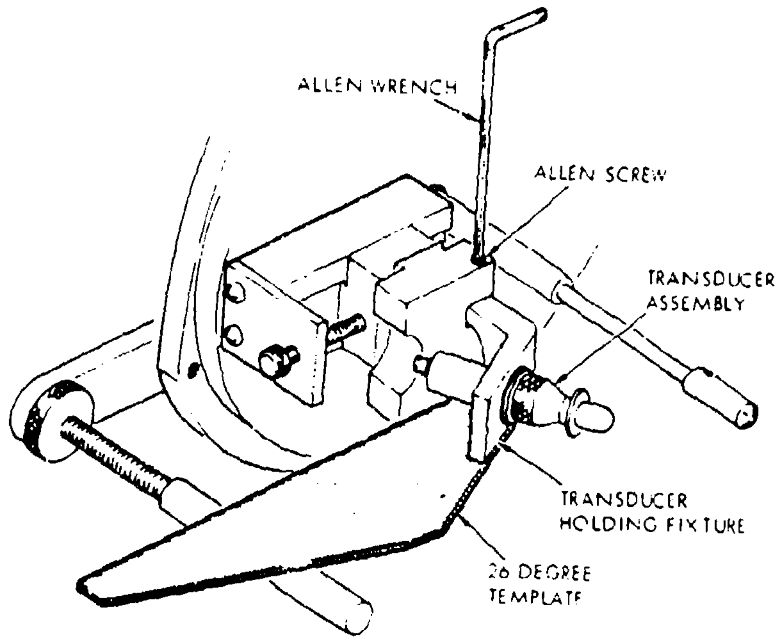
f. With the Scanning System properly calibrated, apply couplant to all accessible fastener holes in the wing planks of structure Sample A and inspect each fastener hole with both transducers.

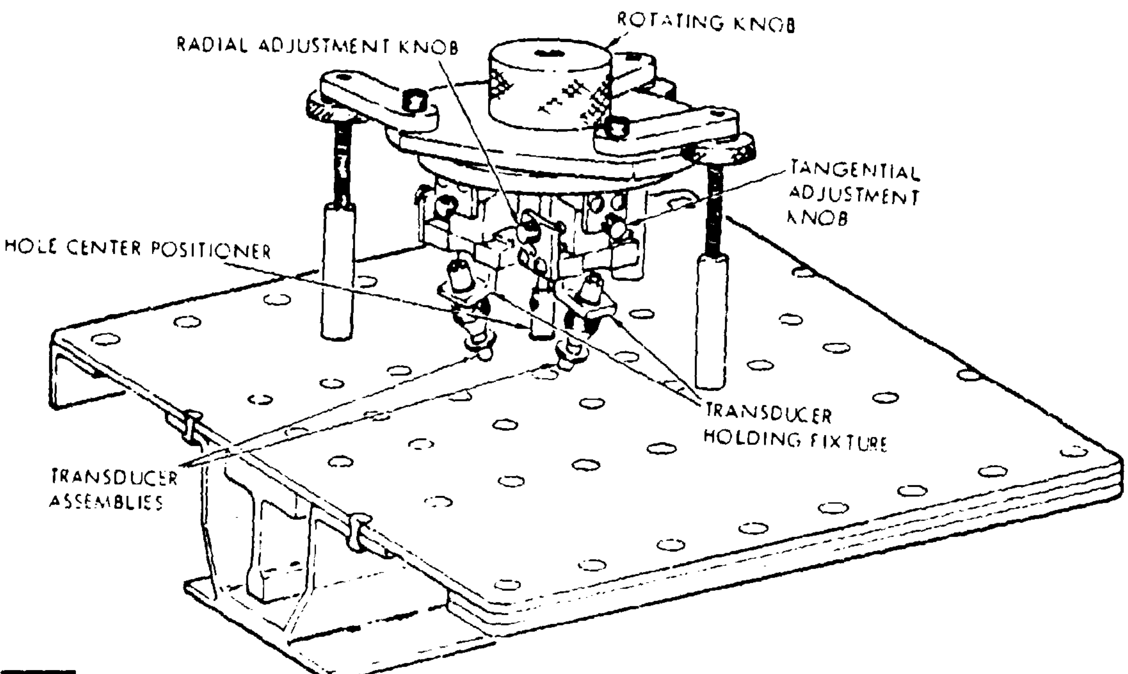
g. Mark and report indicated defects.

D. On page 2-3, revise paragraph 2-6 title to read as follows:

2-6. NDI PROCEDURE NO. 3 - EDDY CURRENT.

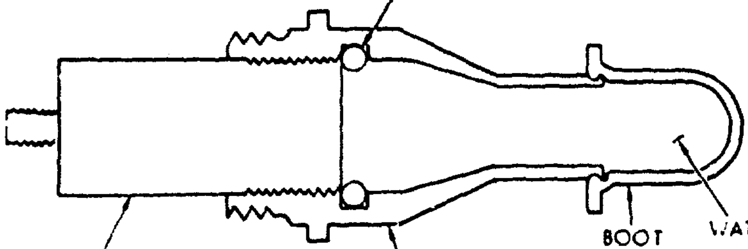
E. Add figure 2-1A immediately following figure 2-1.





NOTE
HOLE CENTER POSITIONER
IS IN HOLE BEING INSPECTED

Figure 2-1A. Setup and Calibration (Sheet 1 of 4)



TRANSDUCER ASSEMBLY

NOTE

1. ASSEMBLE WITH TRANSDUCER SLEEVE AND BOOT UNDER WATER. USE DEAERATED WATER OR WATER THAT HAS BEEN ALLOWED TO STAND FOR 24 HOURS AT ROOM TEMPERATURE, TO PREVENT AIR BUBBLES FROM FORMING INSIDE THE ASSEMBLY. DURING ASSEMBLY, REMOVE BUBBLES FROM THREADED END OF TRANSDUCER AND FROM INSIDE THE SLEEVE AND BOOT.
2. THREAD TRANSDUCER HALF WAY INTO SLEEVE.
3. SLIP BOOT ON END OF SLEEVE AND SEAT BOOT RIM IN SLEEVE GROOVE.
4. COMPLETE THREADING OF TRANSDUCER INTO SLEEVE UNTIL IT SEATS AGAINST "O" RING.

Figure 2-1A. Setup and Calibration (Sheet 2 of 4)

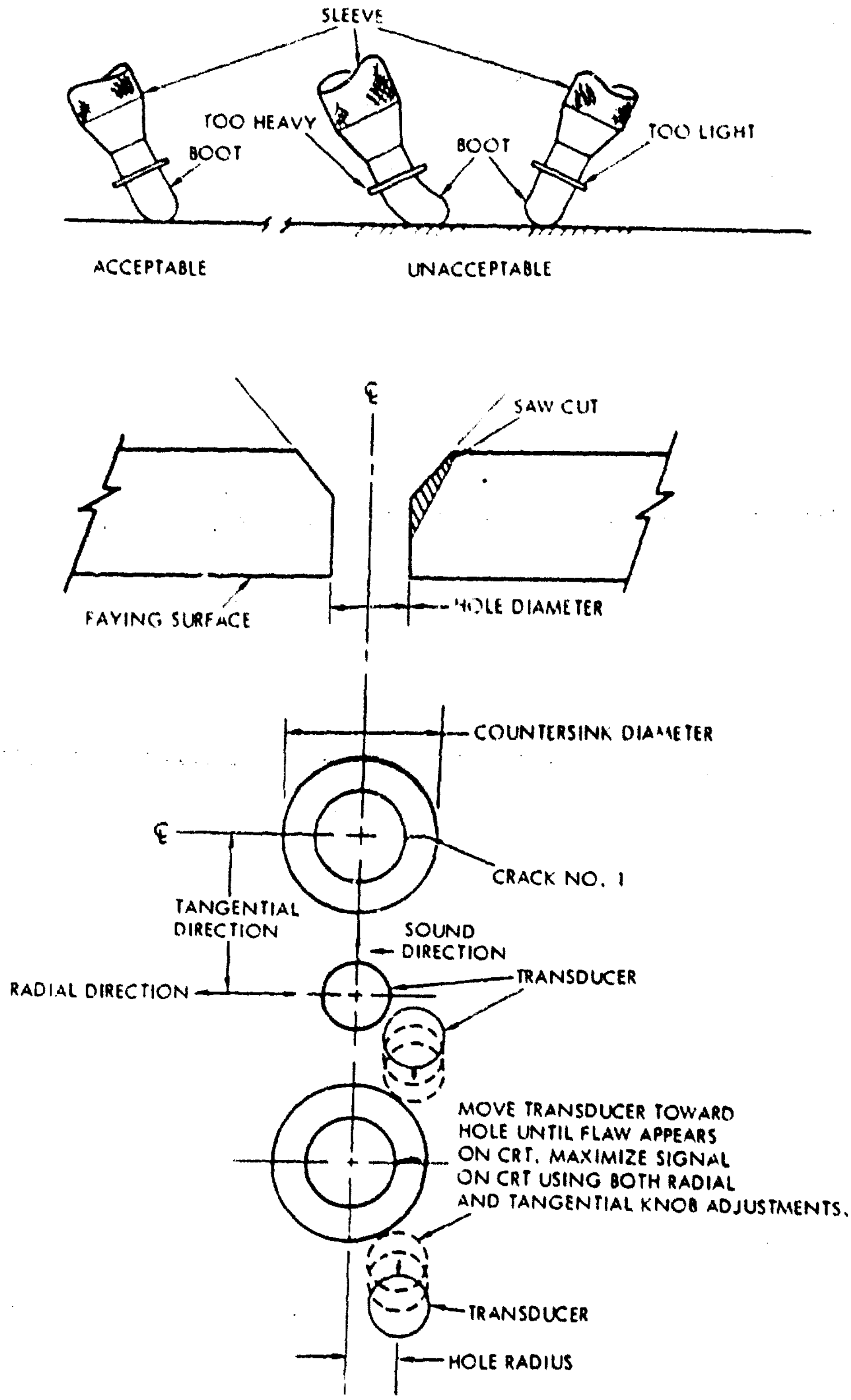


Figure 2-1A. Setup and Calibration (Sheet 3 of 4)

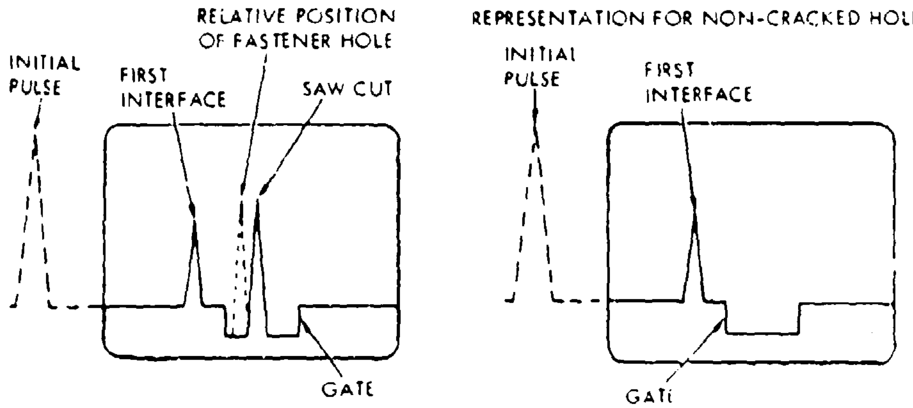


Figure 2-1A. Setup and Calibration (Sheet 4 of 4)

APPENDIX C

INSPECTION PROCEDURES FOR NDI PROFICIENCY SCREENING SAMPLE PROGRAM

INSPECTION PROCEDURES FOR NDI PROFICIENCY SCREENING SAMPLE PROGRAM

This section contains nondestructive inspection procedures to be performed on seventy (70) coupon samples during the NDI Reliability program. Descriptions of the samples and the possible defects are given prior to the (step-by-step) set-up and inspection procedures. The initial settings and calibrations for the ultrasonic and eddy current procedures are contained in Section I of the Nondestructive Inspection Reliability Program technical manual.

NDI PROFICIENCY SCREENING SAMPLES

Description (See Figure 1). The samples made of 7075-T6 aluminum alloy and have an exterior finish of one coat of epoxy primer and one coat of polyurethane enamel. Each sample has two rows of 5 fastener holes in each (ten fastener holes total) containing loose-fit countersunk flush-head steel fasteners. Each sample has an identification number in the upper right corner (when viewed as shown in Figure 1). Test fixtures are provided for holding the fasteners in place and facilitating the inspection.

Defects. All ten fastener holes in each sample are to be inspected for fatigue cracks oriented width-wise of the specimen.

NDI Procedure No. 1 - Ultrasonic

a. NDI equipment:

(1) Reflectoscope, Sperry P/N UM-715 or equivalent.

(2) Transducer, 5.0 MHz 0.250 x 0.250, 60 degree, aluminum, shear wave, Sperry P/N 57A3065 or equivalent.

(3) Cable, 6-foot, Microdot/UHF Connector. Sperry P/N 57A2270 or equivalent.

(4) Video Plug-in Module, 10N, Sperry P/N 50E533 or equivalent.

(5) Couplant, light oil.

(6) Straightedge (Ruler).

(7) Calibration Standard, as illustrated in Figure 2.

(8) Test fixture as supplied.

b. Access: The samples are individually available for bench top inspection. The accompanying fixtures will not adversely affect access for performing the inspection.

c. Preparation of part: Clean local inspection areas as needed to permit good contact between part and transducer.

d. Instrument settings/calibration: Calibrate the instrument for inspection around the fastener holes as follows:

(1) Position the standard in the ultrasonic test fixture with a fastener in-place as shown in Figure 2.

(2) Apply couplant and couple 60 degree shear wave transducer to the surface of the calibration standard at hole 2 in position B, as illustrated in Figure 3, to reflect from the bottom edge of the hole wall.

(3) Refer to paragraph titled Ultrasonic Instrument Calibration in Section I of the manual and calibrate the instrument to display the initial pulse near the left side of the CRT display. Adjust sweep to display signal from the fastener hole near the center of the CRT display.

(4) Place transducer in position A at hole 2 and note that the EDM slot signal position is immediately to the right of the hole signal on the CRT presentation.

(5) Maximize signal from the EDM slot by adjusting the transducer position and set the signal amplitude to obtain 80 percent saturation on the CRT display. Note position of transducer when maximum signal is returned.

(6) Scan positions A, B and C and observe the signals as illustrated.

(7) Now place the transducer in Position A at Hole 0 of the standard and perform the first scan using a straightedge as a guide. In this scan, the transducer is moved lengthwise along the surface of the standard from Hole 0 past Hole 4 so that the transducer moves through the A position for each hole. Note the presence or absence of return signals as the transducer passes each hole.

(8) The EDM slot signal simulates the signal from a crack at the fastener hole.

e. Inspection: Inspect the holes in the samples in a manner similar to step 7 in paragraph d above (instrument settings/calibration), except that eight scans are to be made on each sample as shown in Figure 4. For convenience, directions on the specimens are called out as "forward" and "aft", as in aircraft wing spanwise splice fastener patterns.

(1) Install sample being inspected on the ultrasonic test fixture with all fasteners in place.

(2) Apply couplant to the inspection surface and scan the transducer from right to left on the forward side of each row of fasteners. Reverse the direction of the transducer and scan from left to right on the forward side. Maintain couplant throughout the scan.

NOTE

The scans do not have to be continuous motions of the transducer from one end of the scan line to the other end. The inspector can place the transducer in the correct location at each hole (as indicated in the figure) and manipulate the probe to "search" for a flaw without using the straight edge.

(3) A signal similar to the one obtained during Step d(3) of instrument settings/calibration will indicate the presence of a crack. Be careful not to confuse a reflection from the hole wall for a crack signal.

NOTE

If a small signal is observed to "walk" across the baseline while scanning, place the transducer so that the indication is obtained, then adjust the transducer position and orientation until the indication is maximized. If the amplitude increases considerably, identify the indication as a crack signal.

(4) Repeat Steps e(2) and e(3) for inspection of the aft side of the fastener holes.

(5) Inspect ten holes in each specimen.

f. Mark and report indicated defects.

NDI Procedure No. 2 - Eddy Current

a. NDI equipment:

(1) Crack Detector, Magnaflux P/N ED-520 or equivalent.

(2) Probe Bolt Hole, 3/16 to 1/4 inch diameter. Ideal specialties P/N 1600-3/16 to 1/4-BH or equivalent.

(3) Calibration Standard, aluminum (see Figure 2).

(4) Test Fixture as supplied.

b. Preparation of part: Same as for NDI Procedure No. 1, except that the fasteners are to be removed from all holes prior to inspection.

c. Access: Same as for NDI Procedure No. 1.

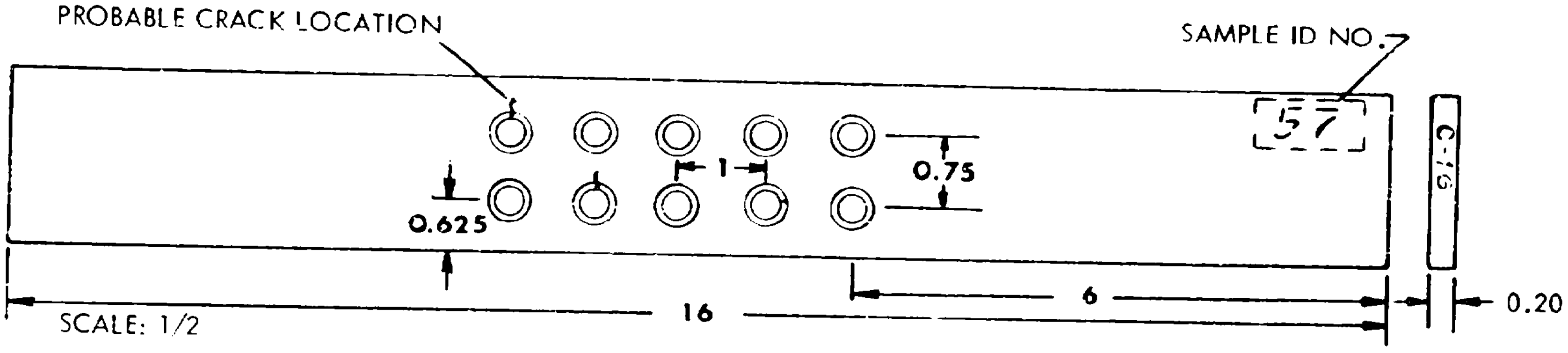
d. Instrument settings/calibration: Refer to paragraph titled Eddy Current Instrument Calibration and Bolt Hole Inspection technique in Section 1 of the manual and use the aluminum standard supplied.

e. Inspection:

(1) Scan the entire inner surface of each hole at two depths in a manner prescribed in step d above and as depicted in Figure 5. Install the specimen being inspected on the eddy current test fixture to facilitate the inspection.

(2) A sharp meter deflection as noted during calibration will indicate a probable crack.

f. Mark and report all indicated defects.



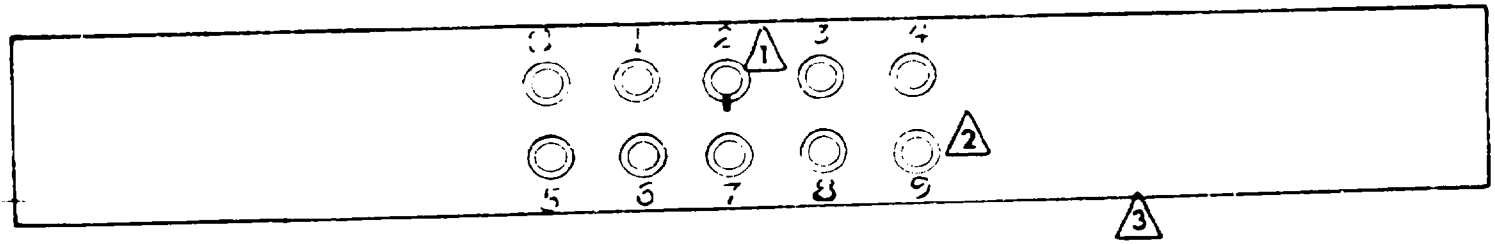
1. MATERIAL: 7075-T6 ALUMINUM

   FINISH: 1 COAT OF EPOXY PRIMER PLUS
   1 COAT OF POLYURETHANE ENAMEL

2. FASTENER HOLES: 0.187 INCH DIAMETER,
   COUNTERSUNK FOR FLUSH-HEAD
   FASTENER, 10 HOLES

3. FASTENERS ARE EASILY REMOVED

FIGURE 1. NDI PROFICIENCY SCREENING SAMPLE



1 HOLE NO. 2 HAS A 0.050 X 0.050 INCH CORNER EDM SLOT ON THE BOTTOM INBOARD SIDE OF THE HOLE (SEE SKETCH BELOW)

2 FASTENERS ARE INSTALLED FOR ULTRASONIC NDI, AND ARE REMOVED FOR EDDY CURRENT NDI

3 MATERIAL IS 7075-T6 ALUMINUM ALLOY 0.200 INCHES THICK

1 EDM SLOT AT BOTTOM CORNER OF HOLE

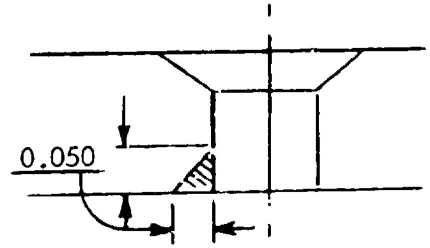
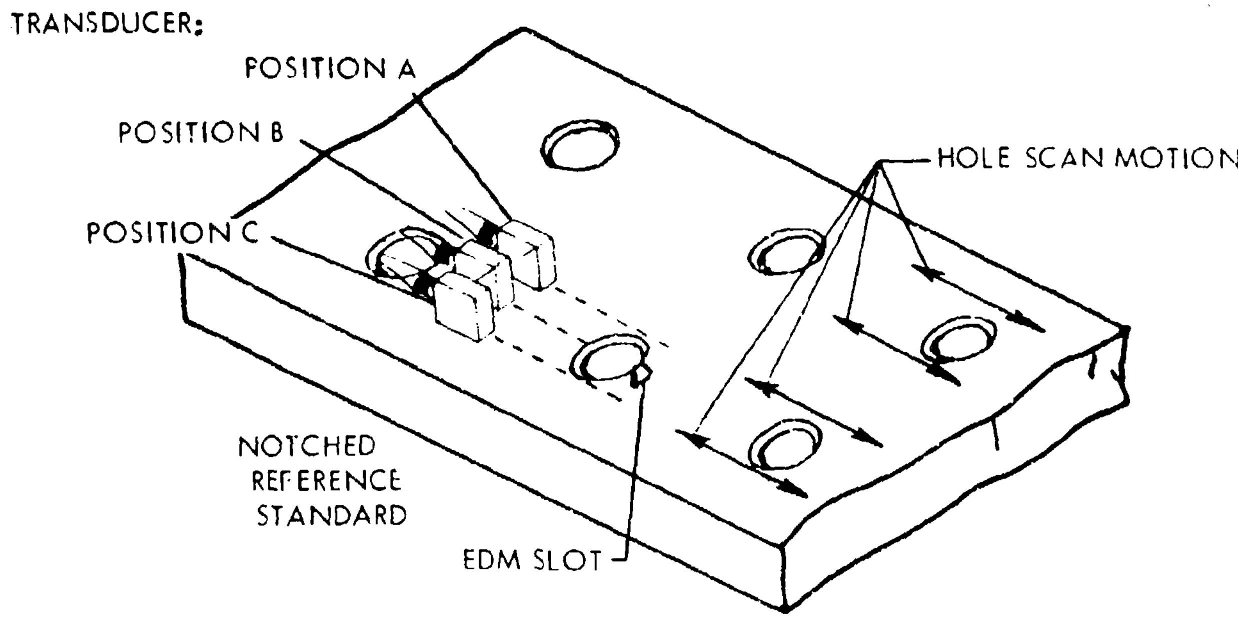
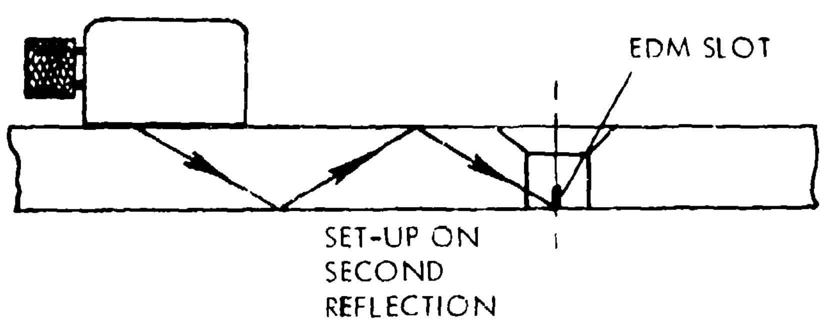


FIGURE 2. INSPECTION STANDARD FOR ULTRASONIC AND EDDY CURRENT NDI



CALIBRATION SET-UP ON STANDARD



TYPICAL CRT PRESENTATION

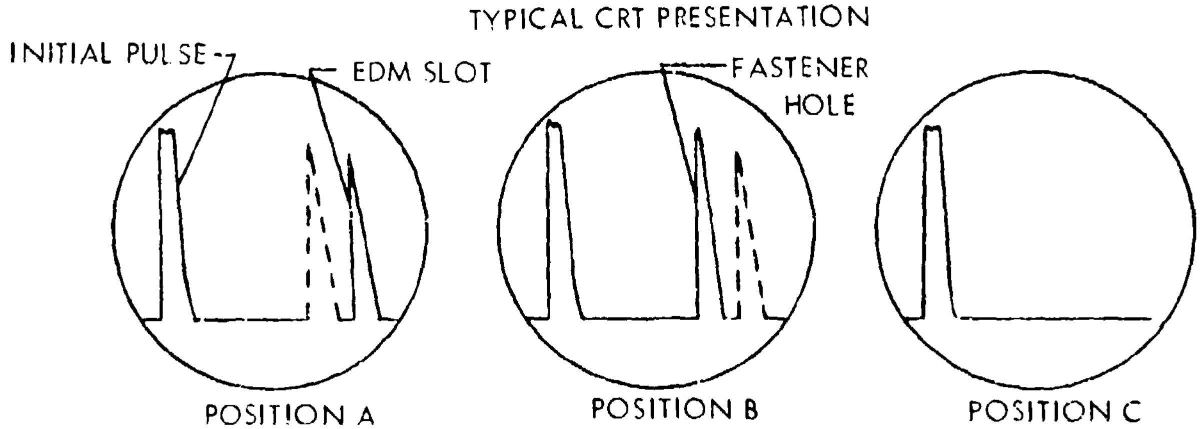
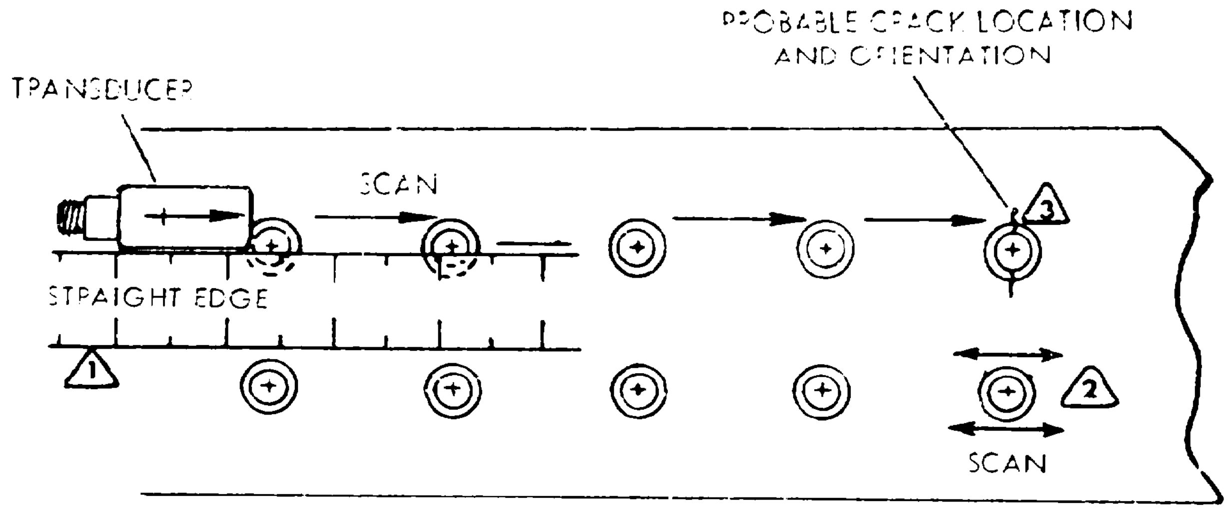


FIGURE 3. INSPECTION OF NDI PROFICIENCY SAMPLES AND STANDARD



1. USE OF A STRAIGHT EDGE TO GUIDE TRANSDUCER. STRAIGHTEDGE IS OFFSET ABOUT 1/32-INCH FROM FASTENER CENTERS.

2. SCAN BOTH SIDES OF HOLE IN TWO OPPOSING DIRECTIONS ON EACH SIDE.

3. PROBABLE CRACKS MAY RUN IN "FORE" TO "AFT" DIRECTIONS AWAY FROM HOLE WALLS.

FIGURE 4. POSITIONING OF PROBE AND METHOD OF SCANNING FOR ULTRASONIC NDI

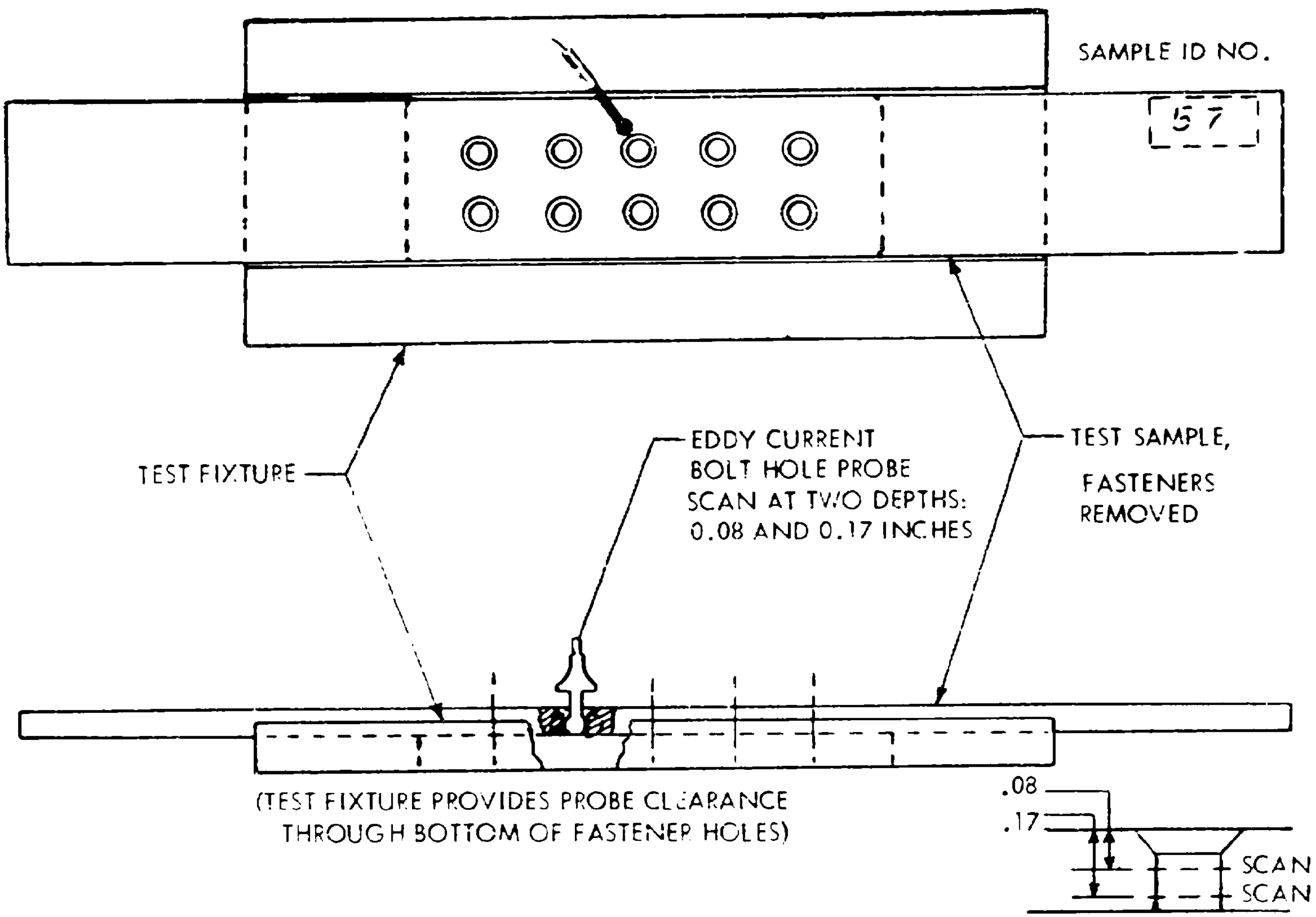


FIGURE 5. EDDY CURRENT NDI OF PROFICIENCY SCREENING SAMPLES